RELIGIO CHEMICI.

ESSAYS

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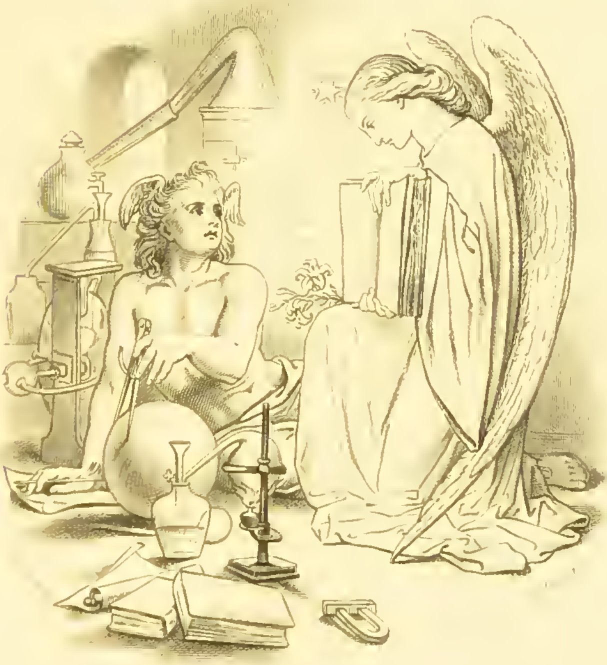

All things were made by Him; and without Him was not anything made that was made. In Him was life; and the life was the Light of Men.—JOHN i. 3, 4.

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TO

JOHN CAIRNS

THESE WRITINGS

OF

THE FRIEND HE SO DEARLY LOVED AND CHERISHED

ARE GRATEFULLY DEDICATED.

'*Jonathan and David made a covenant, because he loved him as his own soul.*'

PREFACE.

George Wilson had it in his heart for many years to write a book corresponding to the *Religio Medici* of Sir Thomas Browne, with the title *Religio Chemici.* Several of the Essays in this volume were intended to form chapters of it, but the health and leisure necessary to carry out his plans were never attainable, and thus fragments only of the designed work exist. These fragments, however, being in most cases like finished gems waiting to be set, some of them are now given in a collected form to his friends and the public. In loving remembrance of his purpose, the name chosen by himself has been adopted, although the original design can be but very faintly represented.

The Biographical Sketches here given are, in like manner, centres, around which more extended researches were to group themselves; but, as each is complete in itself, it is believed many will welcome them as old friends, the dearer because long known; whilst to others they will come with the freshness of first love.

Many thanks are due to Dr. Vaughan, the editor of the *British Quarterly Review*, for permission to reprint articles

which appeared in that periodical; to Adam Black, Esq., in whose *Edinburgh Essays* for 1856 the lecture on *Chemical Final Causes* was published; and to Messrs. Longman and Co., who issued the *Chemistry of the Stars* in No. 26 of their *Travellers' Library.*

Thoughts on the Resurrection are printed now for the first time, and are, like the others, fragments of a larger design. The Address was given at a devotional meeting for Medical Students, held periodically in Edinburgh during one of the University Sessions.

An attempt is made, in sending forth this volume, to meet the strongly-expressed desire of many, for more of George Wilson's writings: how far the attempt has been successful it is for others to say.

JESSIE A. WILSON.

EDINBURGH, ELM COTTAGE,
April 1862.

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RELIGIO CHEMICI.

RELIGIO-CHEMICI.

CHEMISTRY AND NATURAL THEOLOGY.[1]

THE recent appearance of a new edition of Dr. Prout's 'Bridgewater Treatise,' and the publication, not long before, of the 'Actonian Prize Essay,' induce us to think that the present is not an unsuitable occasion for showing that chemistry is not behind the other physical sciences in rendering service to natural theology. It is not likely that for some time we shall see a new discussion of chemistry in this relation, nor shall we readily find more accomplished chemists than the authors of the works placed at the head of our article. Dr. Prout is one of the most distinguished of our senior chemists, and Professor Fownes one of the ablest of the juniors. The former furnishes the results of the investigations and meditations of years; the latter, himself an original observer, brings to the discussion an accu-

[1] (1.) *Chemistry, Meteorology, and the Function of Digestion, considered with Reference to Natural Theology.* By William Prout, M.D., F.R.S., Fellow of the Royal College of Physicians. Third Edition. London, 1845.

(2.) *Actonian Prize Essay. Chemistry as exemplifying the Wisdom and Beneficence of God.* By George Fownes, Ph.D., Professor of Practical Chemistry, University College, London. London, John Churchill. 1844.

rate acquaintance with the most recent discoveries. Both are able writers, but their works are much more valuable as treatises on chemistry, than as discussions of its bearing on theology. On this we shall have somewhat more to say, further on, but meanwhile, we propose, without subjecting these works to detailed criticism, to endeavour to give our readers some conception of the way in which chemistry assists, as well as perplexes, natural theology.

An argument of a twofold kind is deducible from chemistry, in proof of the existence of a great Designer and an Omniscient Chemist. In its one aspect, it considers matter as displaying the characters of what, for want of a more dignified and equally appropriate term, we must call a 'manufactured article.' In this respect, it seeks to show, that the properties of chemical substances are regulated by laws most uniform, most simple, and harmonious; and proceeds thereafter to infer that there must have been an Author of all this uniformity, simplicity, and harmony; and that these are reflections of similar attributes of his own being. The scope of this argument excludes entirely from notice any relation which may subsist between the properties of chemical substances and the welfare of living beings whose bodies are fashioned out of them, and whose life may be compatible only with the properties which are found to exist. It professes, from a consideration of the qualities of matter, apart from all uses to which that matter may be put, to show that it owes its existence and attributes to the will of a Great Creator, and that it proves him to be 'excellent in counsel, and wonderful in working.' Into this, which is the more limited and more difficult part of the chemical argument for a God, we do not propose, on this occasion, to enter. It would require an amount of space in the mere enunciation of the purely physical facts,

on which the theological argument should afterwards be founded, such as we cannot at present command. Nor could the discussion be easily made to run so, that the great mass of our readers should follow it with pleasure, and leave it with profit. We shall not, accordingly, pursue it at all.

The other and more familiar form of the argument from chemistry for the existence of a Creator, is that which considers this science not as complete in itself for that purpose, or as sufficient, when taken alone, to supply proof that there is a God; but as acquiring significance for that end only when taken in connexion with the living beings (plants, animals, and men) which are indebted to it for the elements of their frames, and beholden to it for the maintenance of those functions, the arrestment of which brings life at once to a close.

The atmosphere, for example, which we shall select as the text whereon to discuss the limits and kind of assistance which chemistry lends to natural theology, is a mixture of oxygen, nitrogen, carbonic acid, water-vapour, and ammonia, which, considered in itself, would not be looked upon by most persons as good or bad, as directly supplying evidence of the absence or the presence of design. But when we consider it in connexion with the fact, that every living being on the dry land is bathed in it, and lives on it, and by it, and that those that are in the sea drink it in, dissolved in the element in which they live, then certain conclusions force themselves upon us, concerning the cause why it proves so exactly suited to the necessities of all the animated beings for whom it is the breath of life.

With a view to put the question before us in the clearest light, we shall suppose that it had pleased God, after creating and fashioning this globe, and fitting it for the residence

of living beings, to have himself abstained from adding to it an atmosphere, but, as a mark of favour, to have commissioned one of his angels to do so. Let this angel be further supposed to have been a most accomplished anatomist, botanist, physiologist, and chemist, and to have had the chemical elements and their compounds entirely at his command, so as to have been free to make any use of them he pleased.

To our angel philosopher the following task is assigned: —To furnish an atmosphere fitted to maintain in full vigour the life and health both of plants and animals. This atmosphere must, further, be of such a nature that neither class of living beings shall impair its suitableness for the other, but, contrariwise, shall be a powerful means of preserving it in a salubrious state for the opposite class: the plant constantly adding to it food for the animal; the animal constantly supplying food for the plant. Moreover, it must be as nearly as possible quite uniform in composition, and as pure in one direction as in another, and must contain within itself a power of self-purification, so as to be able to remove or destroy all substances injurious to animal or vegetable life, which may find their way into it. This much settled, our angel proceeds to work in the selection of ingredients for an atmosphere. In the first place, he is aware that neither plants nor animals can live or grow for any length of time in darkness, but must be exposed (speaking generally) for at least some twelve out of every twenty-four hours to the influence of light. No dark-coloured gas, then, which would absorb and extinguish the sun's rays in their passage towards the earth, can be admissible as a permanent constituent of the air. The ruddy-brown nitrous acid and bromine, accordingly, the purple-vapoured iodine, and yellowish-green chlorine, are all, on account of their

colour, even if not otherwise objectionable, quite out of the question.

In the second place, the gas must be tasteless and inodorous ; for neither plants nor animals can exist, unless for a short period, in any of the odorous or sapid gases. Chlorine, bromine, iodine, and nitrous acid are on this account again excluded ; and so are all the gases, simple and compound, excepting oxygen, nitrogen, hydrogen, and perhaps some of the compounds of carbon and hydrogen.

In the third place, the gas or gases of the atmosphere must possess a considerable solubility in water and saline aqueous solutions, for they must be able to become liquid in the blood to produce certain changes there ; and to dissolve in lakes, rivers, and the sea, so as to maintain the respiration of the animals living in them. On the ground, then, of their sparing solubility, nitrogen, hydrogen, and carbonic oxide must be excluded. On the other hand, the solubility must not be very great, otherwise the blood will be supersaturated, and prove too exciting, and the bodies of water on the surface of the earth will dissolve too much, and thereby come to be hurtful to their inhabitants, whilst they rob the atmosphere of too large a portion of its vital ingredients. On this account then, as well as on others, chlorine, bromine, nitrous acid, carbonic acid, and nitrous oxide, must all be excluded.

In the fourth place (not to enumerate at too great length the qualities desirable in a respirable elastic fluid), the gas or gases to be breathed by animals must be able to unite with carbon and hydrogen, and to evolve heat in so doing, otherwise, although the other conditions of life were present, the animal would perish from cold.

Upon reflection, it would soon be apparent to our angelic chemist, that of all the gases, simple or compound, there

was but one that possessed the necessary properties—namely, oxygen. The other gases, moreover, would be excluded by him, not because they were deficient in single serviceable qualities, but because each one of them was, on several grounds, quite inadmissible.

Thus, chlorine, bromine, iodine, and nitrous acid possess colour, odour, taste ; are too soluble in water ; cannot combine with carbon, and, in addition, are deadly poisons. Carbonic acid and sulphuretted hydrogen, with the exception of colour, have all the noxious qualities of those gases also. Hydrogen, the carburetted hydrogens, and carbonic oxide, are too sparingly soluble, and cannot unite with carbon and hydrogen ; carbonic oxide, moreover, is a poison, and all have the serious objection of being combustible in oxygen. Of all the gases, there is but one that can for a moment be compared with oxygen—viz., nitrous oxide, or laughing gas. It has the objection, however, of having both an odour and a taste, and of being exceedingly soluble in water and in saline solutions. But what is worst of all, though it may be respired for a short time, not only without inconvenience, but even with pleasure, its continued inspiration occasions violent excitement, and ultimately death.

It appears, then, that oxygen is the only gas which will serve to maintain the life of animals. It is transparent, colourless, tasteless, and inodorous ; has a medium solubility in liquids ; combines with carbon and hydrogen, and evolves heat in so doing. We may suppose our angel, accordingly (whom we assume to be an accomplished philosopher, but not an omniscient one), proposing, in the first place, to construct his atmosphere, so far as animals were concerned, entirely of oxygen. But on making trial of it, he finds that, if taken alone, it proves too stimulating.

The actions of the body go on with undesirable rapidity; much more heat is evolved than the animal requires, it passes into a state of excitement and fever, and if allowed to breathe the undiluted gas, speedily perishes. The indispensable oxygen, then, must be diluted to the strength proper for animal respiration, by some bland, innocuous gas; and there cannot be a moment's hesitation as to where that gas will be found. The colourless, tasteless, inodorous, scarcely soluble, incombustible, negative nitrogen is clearly the diluent required; and we may suppose a series of trials leading our angelic atmosphere-maker to the conclusion, that, though the proportions might vary to some slight extent, in the one direction or the other, without causing the immediate destruction of animals, sustained life was compatible only with the respirable mixture containing four-fifths by volume of nitrogen, and one-fifth of oxygen. Animals in lakes, rivers, and the sea, having cold blood and a sluggish circulation, may have more oxygen than those breathing air by lungs, but it is not necessary to make a special additional provision for them, as it is secured by the circumstance that oxygen dissolves in water to a greater amount than nitrogen does. Water-animals are by this simple device, supplied with a more oxygenated air, suited to their peculiar condition.

It may here be asked by some thoughtful person, if nitrogen plays no other part in reference to animal respiration than to dilute oxygen, might not the same end have been equally well gained by diminishing the respiratory organs of animals, so as to have had them four times smaller in capacity than they are? They would then have been filled at each inspiration, with one-fifth of the volume of air which at present enters them, so that the atmosphere might have consisted entirely of oxygen. In reference to such

a suggestion we would observe, in the first place, that we have no right to assume that nitrogen is of no use to an animal, merely because we cannot show that it is of service ; and secondly, that such is the balance of organs in a living creature, that the dimensions of one could not be altered without requiring an alteration in the size or capacity of all. If we alter the lungs, we must alter the heart, the blood-vessels, the nerves, — indeed, the whole animal. Now, without entering into minute discussion, we may suppose, that on the whole, even so far as the animal alone is concerned, it might be better to dilute the oxygen by a negative gas, and so maintain the bulk of the animal considerable, than to give it undiluted oxygen to breathe, at the expense of dwarfing and altering its whole organism. Moreover, we are not entitled to assume, that oxygen given alone, would have the same effect as that gas mingled with four times its volume of nitrogen. In all probability it would not. We are not called upon, however, to enter into these discussions, but are entitled, on the other hand, to protest against any such suggestions being made as we have for a moment turned aside to consider. In such an argument as the one we are pursuing, we must either accept the animal as we find it, and consider whether or not the constitution of the atmosphere harmonizes with its necessities, or accept the atmosphere as it is, and ask whether the animal is so constructed as to live within it. We are at present, however, discussing the subject solely as chemists : it is quite competent for us to suggest, if we can, improvements on the atmosphere, but we are not at liberty to change the structure of the animal.

Neither, perhaps, is it impossible to indicate positive benefits which flow to all nature from the presence of nitrogen in the atmosphere. We would venture to suggest, in

the face of those constant declarations, that no use can be found for it,—that it was necessary for the welfare of animated beings that the mass of the atmosphere should be considerable, and this for many reasons; among the rest for these three :—

First.—Because the vicissitudes of temperature at the earth's surface would be much greater than they are, and, in truth, would be incompatible with life, if there were no atmosphere to temper the extreme alternations of heat and cold, which would occur on a naked globe. Our atmosphere equalizes, more or less, the temperature of the earth, as in small islands like Madeira, lying far out in the ocean, the climate is rendered equable by the mass of water surrounding it, which cools it in summer and warms it in winter. We do not desire to affirm, that it was necessary that our atmosphere should have neither more nor less than the bulk it possesses, in order to temper our climate. It would be very difficult to find data from which to decide positively on this point. All that we say is, that it was requisite the volume of air should be considerable.

Secondly.—A mass of atmosphere was necessary, that there might be considerable refraction of the solar rays, and a corresponding scattering and diffusion of the light, heat, and other agencies of the sunbeam; otherwise, certain essential conditions of animal and vegetable life would not be fulfilled.

Thirdly.—A large volume of air was required, in order that great winds might be produced in it, by the rarefying action of the sun's rays, and the revolution of the globe round its axis. We need not stop to remind the reader how these winds bring us clouds, and carry them away, waft us fertilizing showers, and when they are too abundant, sweep the earth dry again: how they plough up the

deep, and refresh all living things there ; how they transport man and other animals over the sea, and in a thousand other ways are ministers of good.

Now, it would have been (so to speak) a waste of force to have made the mass of air of a gas having powerful chemical affinities, seeing that these are not needed ; an inert, elastic fluid, susceptible of vibrations and undulations, being all that is required. This, however, is to say too little ; any of the readily combining gases would have been positively prejudicial. We have already seen that the air could not have had its volume increased by addition of oxygen, for that would have poisoned the animals. Moreover, it would have corroded the rocks at the earth's surface ; oxidized every oxidable body ; and wasted all things. To the other elastic fluids still greater objections apply. No gas would do half so well as nitrogen, for increasing the mass of our air without altering its properties otherwise than by dilution. What water is among liquids, in blandness, neutrality, and indifference, nitrogen is among gases.

On the whole, then, we may suppose our angel-chemist, after such a balancing of considerations as we have been discussing, and not being at liberty to alter the constitution of the animal, satisfying himself that the best possible atmosphere he could mingle for sentient living beings would be one consisting chiefly of nitrogen, and with a fifth of its volume of oxygen.

Having, then, provided for the welfare of the animal, our angel turns to the plant. It appears that the latter requires, speaking generally, four substances to maintain its growth ; namely, certain inorganic salts, which, in general, it obtains from the soil ; water, ammonia, and carbonic acid, which it looks for from the atmosphere. Supplied

with these, it asks no other food, whether moss or oak-tree, but with its wonderful and quite inimitable chemistry, transmutes them into hard wood, green leaves, and beautiful flowers.

A certain proportion of water-vapour, then (which, in truth, is as necessary for the animal as for the plant), must be added to the atmosphere; likewise carbonic acid and ammonia. The quantity of the two latter will be determined by the number of the plants which are to grow at the same time on the surface of the earth. Let us in the meanwhile, however, not to complicate the problem, suppose the question of quantity left out of sight, and be content with an atmosphere, in which a certain unspecified number of plants and animals may live together.

It remains to ascertain that neither class of living beings shall injure the atmosphere for the other. The problem, however, is found to solve itself.

The oxygen which the animal breathes, it converts into carbonic acid, and water, and returns as such to the atmosphere. These the plant appropriates, disposing of the water to suit its own exigencies, making no use of the carbonic acid during darkness, when it sleeps, but drinking it in at every pore as soon as daylight awakes it, taking from it its carbon, and returning its oxygen to the air. There is no accumulation, then, of carbonic acid in the atmosphere, which would kill the animal, for the plant destroys it as fast as it forms. Neither is there accumulation of oxygen, which would ultimately slay both plant and animal, for the latter consumes that gas as quickly as the former supplies it. As for the ammonia, no additional device is needed to furnish it for the plant. The animal supplies it, as well as, in part, the carbonic acid. During life, the animal is evolving ammonia, which reaches the atmosphere,

and nourishes the plant; and when the former dies, in return for feeding, directly or indirectly, on the vegetable during life, it leaves it a legacy of its flesh, blood, and bones, converts itself into carbonic acid, water, and ammonia, and leaving its inorganic salts in the soil, to be appropriated by the roots of the plant, ascends into the air, and feeds it through its leaves.

All this our angel foresees, and also that there shall not only be a constant mutual dependence between plants and animals, but likewise a balance as to relative numbers. For, if the plants shall strive to outgrow the animals, they will be stopped by a deficiency of carbonic acid and ammonia to maintain them; and if the animals shall seek to outstrip the plants in number, they will be poisoned by the accumulation of carbonic acid and the deficiency of oxygen. Each class, then, of living beings will control the other, and maintain its own privileges.

As to further provisions for maintaining the purity of the atmosphere, it appears, on reflection, that none are needed. If any organic bodies are carried up into it, being compounds of carbon, oxygen, hydrogen, and nitrogen, and all oxidable, they will be converted into carbonic acid, water, and ammonia, and do service instead of harm. If any soluble inorganic bodies find their way into the air, they will be carried down again to the earth by the rain when it falls. And insoluble inorganic substances, being none of them volatile, cannot be raised into the atmosphere.

All this, then, being foreseen, we may suppose our angel atmosphere-maker about to mingle the ingredients we have named, when it suddenly occurs to him that such a mixture as he proposes to make, will not remain homogeneously mingled, however thoroughly its ingredients may be at first incorporated.

With the properties of individual gases he is fully acquainted, but not with all their actions on each other. He knows, however, that all kinds of matter obey the law of gravitation, and that liquids which do not act chemically on each other, arrange themselves according to their relative densities. If it should be so with gases—and why should it not?—what will become of his atmosphere? The carbonic acid will descend dry, and poison the parched-up plants and animals. The oxygen will float in a layer above it, the nitrogen above that, and far out of sight, the watery vapour will form an encircling zone, above which any stray hydrogen, or other light gases, which are thrown into the air, will arrange themselves in thin concentric spheres. In such an atmosphere, not to mention other peculiarities, every object on the earth's surface which reflected light, would be mirrored in fantastic images, like those of the mirage and the *fata morgana*, at the lines where the different strata meet.

All the goodly chemical contrivance already recorded seems likely, then, to go for nothing. The problem proposed to our angel he cannot solve, with the data which we have supposed furnished to him, and he returns to the great Creator, to confess, that whilst that universal law of gravitation relentlessly rules all things, he must be foiled in every attempt to clothe the earth with a respirable atmosphere.

The reply of the Author of all things we may suppose to be, that the law of gravitation, though wide in its bearings, is not universal, but can be suspended or overruled by other laws, when its operation is inconvenient or hurtful to the creatures who live under its influence; and that its action being prejudicial in the circumstances supposed, another law takes its place. Our angel is instructed, that though gases

gravitate like other forms of matter, and exhibit greater differences among their relative weights than either solids or liquids do, nevertheless, when they meet, each acts as a void or vacuum to the other, and they intermingle completely: so that not only will any number of elastic fluids, if once mixed, remain homogeneously mingled, but every gas or gaseous mixture possesses a power of diffusing equally through itself any new gas added to it. The problem of a respirable atmosphere is now solved; and here we may bid farewell to our angel, and descend to breathe the air provided for us. Perhaps we have made too much of him, but there seemed something unnatural in assigning the task of atmosphere-making to a mortal, who both had an interest in its construction, and who, moreover, must have been miraculously preserved till that atmosphere was furnished for him.

How beautifully that property of interdiffusiveness among elastic fluids, comes in to crown and complete the other beneficial qualities of the atmospheric gases, will now be apparent. Every chemist who has written on his science as supplying proof of design, has dwelt long and lovingly on this law. We do so likewise, because the idea of a great Designer is never so fully brought out by physical science, as when a law permitted up to a certain point to rule without let or exception, is all at once suspended, and its place supplied by another. The example in the case before us, is the more instructive that the force overruled is the most universal of all known physical influences — that, namely, of gravitation. In general, science deals only with forces and powers, and carries us, at best, back to a great first *cause;* but here, if anywhere in the circle of her dominions, we seem, if but for a moment and dimly, to catch something like a glimpse of a personal God, saying to one

law, 'Hither shalt thou come, but no further, and here shall thy power be stayed,' and calling for another that was not, and it is, and all nature acknowledges a new rule.

We would pause, then, for a moment, to point out a little more fully than we have yet done, how beautifully this force or law of gaseous diffusion works in nature.

It may seem at first sight, as if the law were an almost unnecessary provision; for the winds, it may be said, would intermingle the gases, and sweep away carbonic acid, for example, from the places where it was generated, and the currents occasioned by combustion would carry off that produced by fire. Moreover, it may be urged, that this poisonous gas would not accumulate in the air, for the sea and other waters would dissolve it, and remove it from the atmosphere; and even if it did collect there, the mass of air is so great, that all the carbonic acid produced in a century would not sensibly deteriorate it.

Without entering into minute discussion on these statements, it may suffice to say, that to maintain the atmosphere uniform in composition by the action of winds, would require tremendous hurricanes to sweep in every direction through it, and even the fiercest winds would only effect a most imperfect mixture. The currents occasioned by combustion would carry the noxious gases but a very short way, and would soon let them fall. Solution of the carbonic acid in the sea would kill all the living creatures there; and although it is true that the impurities added to the atmosphere are very small in quantity compared with its mass, it is equally true that they would prove most destructive to life, if not diluted through its entire volume; and without the law of diffusion no such dilution could occur. Even if all the forces we have supposed able to supplant diffusion were

at work, they would in many cases utterly fail to ward off evil. A solitary sleeper in a confined chamber, could gain nothing from the winds, or thermo-currents, or the far-off sea. The carbonic acid from his lungs gathering heavy round his head, would soon steal away his senses. His breath would be to him the breath of death, and his first sleep his last. As it is, though we were inhabitants of an atmosphere as motionless as that in which the Ancient Mariner and his crew lay becalmed, and not one breath of wind stirred the still air, yet this silent and resistless force would lift up as on wings the heaviest gas, and send it to the limit of the atmosphere; and make the lightest descend like a shot bird, even to the very bottom of the deepest mine.

Few, perhaps, of our readers have considered how, but for this force, rain and dew would long ago have ceased to fall, and the green earth have been parched and dried up like a desert. 'All the rivers run into the sea, yet is the sea not full. From the place whence the rivers came, thither they return again.' And why is it so? even because this force of diffusion, when assisted by the sun, is able to lift up the ocean itself, and to make it thin air.

We have all watched with delight a drop of dew lying in the cup of a flower; but few marvel at the fact, that that little drop returns to the air whence it came. Why should it not lie in its flower-cup for ever? A pearl lies at the bottom of the sea, and makes no effort to float up to the surface; and yet the difference in density between the pearl and the sea, is much less than that between the dew-drop and the air. A globule of quicksilver let fall into the ocean rests in its bed for ever, yet it is only some eleven times heavier than the water above it. The dew-drop is 815 times more dense than the air, and there are hundreds

of tons of the latter pressing on it; but no sooner does the sun arise, than it brightens and exhales to heaven. It bounds up like a bird into the blue sky. The air opens its arms for it, and lifts it into its bosom, and by and by spreads it from pole to pole, and it encircles the world.

The atmosphere thus solicits and encourages—nay, compels the rise of vapour, and keeps undiminished an embryo store of refreshing dews and warm showers for the earth, and so it ever holds good that 'the clouds come after the rain.'

One last reference to this law. But for it, all other contrivances for maintaining the life of animals would have totally failed to secure that end, for respiration would have been impossible. To sentient beings, the atmosphere would have been as useless as the most dainty and nutritious food is to one who has not the power to swallow. There is this perplexing problem to be solved in the case of respiration. An animal has not two sets of air-tubes, as it has two kinds of blood-vessels, along one of which (the arteries) the blood goes, whilst by the other (the veins) it returns. There is only one windpipe in animals, by which the oxygen may travel to reach the blood, and the carbonic acid return to reach the air. By the same channel we must constantly cause two counter or reverse currents to pass: a stream of oxygen from the outer air to dissolve in the blood; a stream of carbonic acid from the blood to dissipate into the air. The breathing-tube of an animal is thus like a railway tunnel, through which trains are constantly passing in opposite directions, and yet there is but one pair of rails.

There is no mechanical or vital device for effecting the transference of the opposing aërial currents; no living alternating pump like the heart, which should this moment suck oxygen into the blood, and the next moment suck carbonic

acid out of it. The muscles of the chest, by their action, alternately fill and empty the larger wind-tubes, or what we may call the lobbies of the air-galleries. It is only in the narrow passages and distant corridors, that the blood and air meet and act on each other. There, however, the pantings and heavings of the chest have no direct effect in filling or emptying the air-channels. It is all occasioned by the power of diffusion. The issuing carbonic acid acts like a vacuum to the entering oxygen, or at most, neither gas resists the passage of the other, more than the pebbles in the bed of a stream do the water flowing over them. They glide past each other, impelled by an irresistible force, which obliges them to change places, so that a certain volume of the one cannot by possibility travel in one direction, without permitting, nay, without compelling, a certain volume of the other to pass in the opposite one. The gases entering and leaving the blood are like weights hanging at opposite ends of a string suspended over a pulley, or like the buckets in a well. The one cannot sink without causing the other to ascend, or either move in one way, without causing the other to move in the reverse one. There are animals in which the air-tubes are as rigid as iron, so that they cannot expand or contract to carry air to or from the blood. In these the force of diffusion alone maintains respiration, but without that force it could not go on in any class of terrestrial beings. So much for this wonderful law.

The analytical method we have followed in studying the chemistry of the atmosphere, has had the necessary disadvantage of compelling us to pursue it bit by bit, and, as it were, piecemeal. We must now try to conceive of the atmosphere as a whole, and to realize clearly the idea of its unity. And what a whole! what a unity it is! It pos-

sesses properties so wonderful, and so dissimilar, that we are slow to believe that they can exist together. It rises above us with its cathedral dome, arching towards that heaven of which it is the most familiar synonyme and symbol. It floats around us like that grand object which the apostle John saw in his visions—'a sea of glass like unto crystal.' So massive is it, that when it begins to stir, it tosses about great ships like playthings, and sweeps cities and forests, like snowflakes, to destruction before it. And yet it is so mobile, that we have lived years in it before we can be persuaded that it exists at all, and the great bulk of mankind never realize the truth that they are bathed in an ocean of air. Its weight is so enormous, that iron shivers before it like glass; yet a soap-bell sails through it with impunity, and the tiniest insect waves it aside with its wing.

It ministers lavishly to all the senses. We touch it not, but it touches us. Its warm south winds bring back colour to the pale face of the invalid; its cool west winds refresh the fevered brow and make the blood mantle in our cheeks; even its north blasts brace into new vigour the hardened children of our rugged clime. The eye is indebted to it for all the magnificence of sunrise, the full brightness of midday, the chastened radiance of the gloaming, and the 'clouds that cradle near the setting sun.' But for it, the rainbow would want its 'triumphal arch,' and the winds would not send their fleecy messengers on errands round the heavens. The cold ether would not shed its snow-feathers on the earth, nor would drops of dew gather on the flowers. The kindly rain would never fall, nor hailstorm nor fog diversify the face of the sky. Our naked globe would turn its tanned and unshadowed forehead to the sun, and one dreary, monotonous blaze of light and heat dazzle and burn up all things. Were there no atmosphere, the evening sun would in a

moment set, and, without warning, plunge the earth in darkness. But the air keeps in her hand a sheaf of his rays, and lets them slip but slowly through her fingers : so that the shadows of evening gather by degrees, and the flowers have time to bow their heads ; and each creature space to find a place of rest, and to nestle to repose. In the morning, the garish sun would at one bound burst from the bosom of night, and blaze above the horizon : but the air watches for his coming, and sends at first but one little ray to announce his approach, and then another, and by and by a handful, and so gently draws aside the curtains of night, and slowly lets the light fall on the face of the sleeping earth, till her eyelids open, and, like man, she goeth forth again to her labour till the evening.

To the ear it brings all the sounds that pulsate through it. The grave eloquence of men ; the sweet songs and happy laughter of women ; the prayers and the praises which they utter to God ; the joyous carols of birds ; the hum of insect wings ; the whisper of the winds when they breathe gently, and their laughter and wild choruses when they shriek in their wrath ; the plashing of fountains ; the murmur of rivers ; the roaring of cataracts ; the rustling of forests ; the trumpet-note of the thunder ; and the deep, solemn voice of the everlasting sea. Had there been no atmosphere, melody nor harmony would not have been, nor any music. The earth might have made signs to the eye, like one bereft of speech, and have muttered from her depths inarticulate sounds, but nature would have been voiceless, and we should have gazed only on shores 'where all was dumb.' To the last of the senses the air is not less bountiful than to the others. It gathers to itself all perfumes and fragrance ; from bean-fields in flower, and meadows of new-mown hay ; from hills covered with wild

thyme, and gardens of roses. The breezes, those 'heavy-winged thieves,' waft them hither and thither, and the sweet south wind 'breathes upon banks of violets, stealing and giving odour.'

Such is a faint outline of the atmosphere. The sea has been called the pathway of the nations, but it is a barrier as well as a bond between them. It is only the girdling and encircling air which flows above and around all, that makes the 'whole world kin.' The carbonic acid with which our breathing fills the air, to-morrow will be speeding north and south, and striving to make the tour of the world. The date-trees that grow round the fountains of the Nile will drink it in by their leaves; the cedars of Lebanon will take of it, to add to their stature; the cocoa-nuts of Tahiti will grow riper upon it; and the palms and bananas of Japan change it into flowers.

The oxygen we are breathing, was distilled for us some short time ago by the magnolias of the Susquehanna, and the great trees that skirt the Orinoco and the Amazon. The giant rhododendrons of the Himalayas contributed to it, the roses and myrtles of Cashmere, the cinnamon-trees of Ceylon, and forests older than the flood buried deep in the heart of Africa, far behind the Mountains of the Moon.

The rain which we see descending was thawed for us out of icebergs which have watched the pole-star for ages; and lotus lilies sucked up from the Nile and exhaled as vapour the snows that are lying on the tops of our hills.

The earth is our mother, and bears us in her arms: but the air is our foster-mother, and nurses each one. Men of all kindreds, and peoples, and nations, four-footed beasts and creeping things, fowls of the air and whales of the sea, old trees of the forest, mosses wreathed upon boughs, and lichens crumbling on stones, drink at the same perennial

fount of life which flows freely for all. Nursed at the same breast, we are of one family—plants, animals, and men; and God's 'tender mercies are over us all.' Must we strive, by rule of logic and absolute demonstration, to shut up each reader into a corner, and compel him to acknowledge that the atmosphere was not self-created, but was made by Him 'who stretcheth out the heavens as a curtain, and spreadeth them out as a tent to dwell in.' Is there any one who can resist exclaiming, 'O Lord! how manifold are thy works, in wisdom hast thou made them all?'

To utter some such exclamation will be the natural dictate of most minds. But let us put aside every attempt to take advantage of emotional feelings excited by appeal, and calmly ask ourselves what we are entitled to build upon the truths we have been learning.

If our readers have assented to the arguments which induced our imaginary atmosphere-maker to choose the constituents for an atmosphere which we have supposed him to select, they will readily acknowledge that it is impossible not to believe that the air was mingled by a being, or by beings, perfectly acquainted with the anatomy and physiology of the plants and animals which were to breathe it and feed on it. The atmosphere, then, has not the characters of a chance compound, but all the peculiarities of a complex mixture, carefully mingled for a special object.

If, then, we acknowledge design, we imply the existence of one or more designers. We cannot take it upon us to affirm, from physical science, that there certainly was but a single designer, and not several acting in concert. We must be content with showing, or endeavouring to show, that a perfect unanimity of counsel prevailed between the maker of the plant and the maker of the animal—the creator of the sea and the author of the earth—the former of

the sun and the deviser of the atmosphere, and then appeal to the love of unity in every man's breast, and ask him if that is not outraged by the cumbrous, unwieldy, and unnecessary hypothesis, that there have been many gods, and not one, employed in fashioning the globe. Let it, however, be freely acknowledged, that physical science can only prove that power, wisdom, and knowledge have been and are at work in the world. Whether they are centred in one Being, or are shared among many, is a problem it cannot undertake to solve.

On the other hand, if it shall appear that there is an *à priori* intuition in our minds of one God; if our consciences shall be found testifying to the difference between right and wrong, and connecting that distinction with one Moral Governor; if human tradition shall be found, amidst all polytheistic expansions, to have at bottom held firm by the idea of a single Creator and Ruler of the world; if an accredited and trustworthy divine revelation shall have assured us of the unity of him who has declared that 'the Lord our God is one Lord,' then physical science will affirm that all creation entirely accords with such a declaration. If any one will assert that it is more probable that there were, and are, several creators and preservers of the world than that there is but one, the burden of the proof, we apprehend, lies with him.

We consider it unnecessary to enter into a formal discussion of the evidence of design, for if the array of proofs we have brought incidentally forward do not establish its existence, there must be a fallacy in the whole argument. Moreover, we take it for granted that all who are satisfied that there is design, will acknowledge there must be a designer. Either, when we see design, we infer that there must be a designer, or we are not necessitated to draw such an inference.

If the latter be true, the whole of natural theology is baseless, and it is quite as probable that the world made itself, as that God made it. We suppose, however, that we have not a single reader who doubts either the existence of design or of a designer. In truth, the argument would be worth very little, if it needed eight Bridgewater Treatises to prove that it was true. A single flower will serve as well as an atmosphere to prove design. Even a grain of sand bears unmistakable marks of the fingers of a most exquisite artist. The marvellous thing would be, if so much as a particle of matter could be found which proclaimed itself to be formless and designless. There is none such in the universe. We should be terrified if we found one.

We suppose it, then, acknowledged that the world gives proof of wisdom, knowledge, and power having wrought, and being at work in it; and pause to ask the question, Does it also show that beneficence is working there?

This is the matter which most concerns us. It is the only part of the problem which, in a moral point of view, we need be careful to answer. Knowledge, wisdom, and power are but means to an end. If they are not wielded by justice, mercy, and benevolence, or if they are guided by evil influences, the designs they work out may have no mark of goodness upon them, or even bear the stamp of utter malevolence.

What, then, is the testimony of physical science on this subject? Does it declare that unthwarted benevolence is found triumphantly working out a great scheme for securing unalloyed and perfect happiness to all under its control? If the answer is not already on our lips, it will soon be. That same atmosphere which brings summer showers, brings winter rains also; sends chilling east winds, cold frosts, and pitiless hailstorms; scatters the seeds of a thousand diseases,

fans and nurses them till they ripen to death, and helps consumptions and fevers to sweep their thousands away. Its diffusive power is not more ready to intermingle the vital oxygen with the other elements of the air, than it is to carry the subtle poison of plague or cholera round the globe. But for it, miasms and malaria would confine their ravages to the spots where they originated, or at worst travel outwards only by slow and warning steps, so that men might flee from them. But to the air they are as welcome as the choicest perfumes of flowers. It will take no refusal, but adds each to itself, and every living being is compelled to drain the poisoned draught.

The air has its warm zephyrs and beneficent trade-winds, but it has also its monsoons and tornadoes, its whirlwinds and hurricanes, which depopulate whole islands and sweep the earth like besoms of destruction. It has its small rain for the tender grass; its warm mantle of snow-down to lay over the young leaves till summer shall come; its refreshing dew for the sleeping flowers; but it likewise holds in its right hand a flaming thunderbolt, with which it shatters navies to fragments, whilst it asks, in the name of God, 'Who can thunder with a voice like him?' How many millions of men have died of diseases of the lungs! Whilst we have been rejoicing over the exquisite adaptation of the atmosphere to the necessities of animals, and to the respiratory organs with which they are provided, hundreds of sufferers have been agonizing under the wasting pangs of consumption, not to mention other diseases. What is this? The lungs of those invalids were made to breathe air, and air was provided for them. What, then, has altogether failed and utterly gone wrong? The vital and sustaining oxygen is burning up the body, and maddening it with fever,—the bland and innocuous nitrogen is exciting fierce

fits of uncontrollable coughing; each note a death-knell. The water-vapour, so necessary to life, is bursting forth in clammy perspiration, swiftly stealing strength away. The bells are all ringing backwards. The instrument that once syllabled music so sweet, is jangling only discords. Are those who are tormented thus solitary sufferers, rendering the happiness of all others only the more conspicuous by the contrast they afford? All men do not die of consumption, nor of diseases of the lungs—but all die. Not one pair of lungs has yet been found, nor any kind of respiratory organ of man or animal, which has not worn out, or what is worse, has not been cut short in its working, and thrown aside like an instrument wantonly destroyed. The exception proves the rule, but there is no rule proved only by exceptions. Our argument set out by declaring that animals were made to live, and furnished with all the means of living; it ends by acknowledging that all die. It has further to admit, that scarcely one of the higher animals perishes by what we can call natural decay, or liken to the winding down, or silent cessation of the moving power of a machine. It confesses, mournfully, that there is not merely death, but likewise suffering; anguish and agony, for which physical science can show no final cause, or see any reason. To this great mystery we seek for a short space to direct the reader's attention.

We count it a great and blameworthy defect in nearly all our recent publications on Natural Theology, that due prominence is not given to the dark as well as to the bright side of Nature. A wrong is thus done to science, to which the perplexed inquirer is sent to read a lesson which it does not teach, and to find depicted a character of God which it disowns. An equal wrong is done to Revelation, which is made to appear as if it gave a less perfect account of the

Almighty than Nature does, and did not proclaim him the infinitely benevolent being which his works show him to be. It seems to us, therefore, a plain and imperative duty to illustrate, by one or two examples, the extent to which chemistry reveals evil as well as good in the world, and thereafter to consider, very cursorily, how far the existence of that evil modifies our views of the benevolence of God. We rejoice to have an opportunity of disavowing the practice so common among recent authors, of slurring over the difficulties of natural theology. Some of them write and speak as if there were absolutely none. Professor Fownes, for example, in his 'Actonian Prize Essay,' carries us through a succession of proofs of benevolence, and scarcely halts for a moment to hint that there is so much as the shadow of a ground for suspecting that this benevolence ever fails, or seems to fail, in its purpose. He appears to have considered, perhaps naturally enough, that the prize was to be given for adducing proofs of kindly design, and to have studiously omitted all reference to anything pointing the opposite way. One of his concluding advices to his reader is, to consider himself in the hands 'of a Being of *unmixed and unbounded* benevolence.'[1]

Others, who have discussed the same question, have lingered but for a moment over the difficulties of their argument, thankful if they could only suggest some most improbable explanation, and pass on to more tractable topics. Dr. Prout, for example, in his 'Bridgewater Treatise,' arrests for a moment his exposition of beneficence, to ask what the evil in nature, real or apparent, means. All, however, that he can offer in the way of explanation on the subject is to ask, 'Who can say that the minor evil may not have been essential to the greater good?'

[1] *Actonian Essay*, p. 153.

'That the poisonous metals, for instance, are not, as it were, the refuse of the great chemical processes by which the more important principles of nature have been eliminated?' It is important to notice what Dr. Prout's argument is. According to him, the poisonous substances in nature are the refuse of the processes by which our world was made; and are as necessarily present in it, as dross, and slags, and scoriæ accompany the manufacture of a steam-engine, or other similar machine. The argument, unfortunately, if it prove anything, proves a great deal too much. There is not one of the metals which does not yield several compounds, which even in moderate quantity are poisonous both to plants and animals; the greater number, after combination with the other elements, are deadly poisons. If poisonousness, then, be the mark or sign of a body being refuse, every one of the metals stands in this predicament; and from gold to iron, each must be looked upon as bearing no stamp of design upon it. Now, the metals are the most abundant chemical elements, 46 out of the 60 being metallic, so that at one stroke, Dr. Prout brands more than two-thirds of simple chemical substances as refuse matter. The remaining 14 non-metallic elements can as ill bide the test, as the metallic ones could. Five of them, chlorine, bromine, iodine, fluorine, and phosphorus, are more powerful poisons than any metal. In truth, there is not one of the metals of itself poisonous, not even arsenic, mercury, or copper. It is not till they enter into combination with some non-metallic substance that they become deadly; and no body is more effectual in rendering them so, than that life-sustaining oxygen which Dr. Prout has specially referred to, as showing marks of beneficent design.

The last nine elements, oxygen, hydrogen, nitrogen, carbon, boron, silicon, sulphur, selenium, and tellurium,

are not poisonous uncombined. Every one of them, however, forms destructive compounds with the metals; in which it is to be observed, that the non-metallic body is as much concerned in conferring the character of noxiousness to vegetable and animal life, as the metallic element is. The poison, arsenious acid, for example, is a compound of the metal arsenic and of oxygen, neither of which is singly poisonous. The deadliness of the resulting body is as much owing to the oxygen as to the arsenic; and so with similar compounds. Moreover, oxygen, hydrogen, nitrogen, and carbon, the characteristic elements of plants and animals, have only to unite with each other to form compounds much more deadly than any mineral poisons. Thus, the chief constituents of air, nitrogen and oxygen, combine to form the corrosive nitric acid. Carbon, nitrogen, and hydrogen make up the most terrible of all poisons—prussic acid; and these are not solitary cases, for the same elements form, by interunion, many other compounds scarcely less deadly.

On inquiry, then, it appears that every chemical element is originally, or becomes by combination, a poison; and as the globe, including its inhabitants, consists solely of poisons, our world is nothing but refuse. When our poet declared of Nature that—

> 'Her prentice han' she tried on man,
> And then she made the lasses,'

every one admired the beauty of the thought. But who ever expected to be told, by way of proving that God was beneficent, that the Creator had served an apprenticeship to world-making, and that, too, to so little purpose, that he failed in the manufacture of the globe we inhabit? One can only forgive the folly, not to say profanity, of the thought, by believing that the author did not see whither his argument led. In truth, he appears scarcely to have

uttered it before he became ashamed of his opinion, for he immediately asks if it be not possible 'that these poisonous principles have not been left with such subdued properties as scarcely to interfere with His [God's] great design,—not because they could not have been prevented — not because they could not have been removed—but on purpose and designedly to display his power?'

It is the absence of anything like a resolute attempt to look this great problem of physical evil in the face, that renders our Bridgewater Treatises so little valuable as works on natural theology. We except entirely from this charge Dr. Chalmers' beautiful volume, which has none of that appearance of being written to order, so unpleasantly evident in some of the others; and we fully acknowledge the value they all possess as scientific treatises. But to prove design, and even benevolent design, is not enough; neither is much elaborate argument necessary to establish its existence. The great mass of mankind are perfectly willing to acknowledge, and to believe, that feet were made for walking, teeth for mastication, and eyes for vision. It is an easy task for an author to prove that these organs were intended for the purposes specified, when he is addressing readers who have all their lives taken for granted that such were the uses they were intended to serve. Let all thanks and honour, notwithstanding, be given to the accomplished men of science who have with so much skill and patience investigated, and rendered intelligible to every reader, the exquisite devices and arrangements with which nature is full; even if they have done no more than illustrate a familiar argument, and justify an anticipated and foregone conclusion. At the same time, however, we are surely entitled to ask, at the hands of those who engage to prove to us that nature is the sum of innumerable contrivances

for securing health, happiness, and life, why it is that disease, agony, and death reign ultimately supreme, and vanquish their opposites?—do these latter flow from the same source as the former?—are they co-ordinate and necessary parts of the system of nature?—have they always existed? —will they ever cease to be?—do they destroy the force of the argument for the benevolence of the Creator?—do they imply that evil as well as good powers have been, and are at work in the world? These and many similar questions, as it seems to us, call for much fuller consideration than they have received at the hands of any of our later writers on natural theology. Our ultimate estimate of the value of the whole argument must be determined by the modes in which we dispose of them; and the slight and unsatisfactory way in which they are ignored, passed by, or summarily dismissed, in works otherwise so able as those to which we have been referring, is the reason, we suppose, why the Bridgewater Treatises on the physical sciences are esteemed by *men* on account of their science, not their theology, and are scarcely read by *women* at all. We count it, that had they fulfilled their purpose, it would not have been so. To intelligent and cultivated women, with their fine sense of harmony, their keen sympathy with suffering, and horror at pain, any honest and earnest attempt to account for the physical evil that is in the world, must have been acceptable, and they would not have declined to master difficulties of chemistry, of anatomy, or geology, had these engaged to lift even a corner of the dark veil which hides God's goodness from us. But they might well forbear attempting the study of intricate and unfeminine sciences, when these promised, at the utmost, to do no more than prove that wisdom and benevolence are attributes of God—a truth which, had they ever doubted it,

they could prove to themselves more pleasingly, and quite as fully, by a glance, like Milton's Eve, at their own reflected images; by the sight of a sea-shell or a summer flower, as by reference to the noxious gases of the laboratory, or to the horrors of the dissecting-room.

To a task so difficult as that of inquiring how far physical science can harmonize the evil she brings to light, with the good, we are not about to address ourselves. We propose only to pave the way for such an inquiry, by pressing upon our readers the reality and extent of the physical evil that is in the world. Two examples of its frequency are all that our space will allow us to furnish. The first of these shall be the occurrence of chemical substances or conditions destructive to vegetable and animal life, and that in circumstances where living beings cannot avoid being destroyed by them. No one could acknowledge more willingly than we have done, that, speaking generally, living beings were made to live and to enjoy life, and that the means for securing them that enjoyment were abundantly provided. It is not the less true, however, that they are not guarded against the destructive influence of agents hostile to life, which frequently exterminate thousands at a stroke. Millions of animals have been seen lying dead at the same time on the shores of the Southern Atlantic islands; countless numbers of fishes have been known to perish at once, by the discharges of submarine springs and volcanoes, which poison the sea for miles around; and earthquakes, volcanoes, tempests, hurricanes, and pestilences deal destruction wholesale to those on the dry land. It has been so, not only since the beginning of the historic era, but from a much earlier period. Among the records of bygone ages, which geology has written down with her lithographic pen, and preserved for ever, are dark

and constantly recurring tales of oceans full of living creatures stifled simultaneously by sudden and swift catastrophes, which gave no warning of their approach, and from the disastrous effects of which there was no escape. Nor have exterminations of this kind been limited to animals low in the scale of organization, like fishes. The giant limbs of the mammoth have not saved him from being reached by a destruction so swift and unexpected, that he has been entombed entire in ice, as flies are found encased in amber, before decay had time to make any impression on his huge carcase. The countless fossil remains of tropical animals found in our own country, appear to indicate that the temperature of our northern latitudes was once much higher than it is now, and that the change in this respect proved as destructive to animal life, as the transportation of the creatures in our equatorial regions to either of the poles would do at the present day. Geology is mournfully full of similar records.

It is not that animals die, but the mode in which they are cut off, that afflicts us. Some physiologists affirm, that no provision or necessity for death can be shown to exist in any animal, which, to all appearance, might, if not invaded from without, live for ever. But the greater number of authors, and assuredly more justly, point out that from the instant when life commences, till its close, a series of changes is going on, which necessitates extinction of vitality. The infant is rosy and plump, with elastic cartilages, and soft, yielding blood-vessels and air-tubes; the old man's blue veins start up, through the thin, wasted, meagre skin; below this, all the fat that rounded off the otherwise harsh outlines of the child, has been slowly and constantly removing, to accumulate round the heart and great arteries; the bones, once supple and yielding, have

year by year been growing more brittle, till they snap through like glass; the arteries are fast becoming rigid, bony canals, and by and by will cease to carry blood; the grasshopper will become a burden, and the golden bowl be broken at the fountain.

These changes are independent of external violence and of disease, and show themselves in all animals. They can only obscurely, and with a certain propriety, be compared to the wearing out of any machine of man's construction; for, in the latter, they are the same materials, weakened by long use and worn out by friction and concussion against each other, that at length cease to move, or give way; whereas in the former, though this also is happening, there is something more going on. The body of the aged man is not that of the middle-aged one grown older, but a quite new body, constructed on a principle of constantly decreasing mobility, and intended to go on changing and becoming less mobile, till it stop altogether. Death coming on animals in this way, would be no King of Terrors; he would be as little fearful, he would often be as welcome, as his twin-brother, Sleep. Death in such a shape would not, we think, be invested by us with positive attributes at all; it would only be *not* life.

If, in this way, we saw an animal developing from its germ, as a flower does from its seed, reaching maturity, retaining this for some time; then declining gradually; and finally, like a watch which has unwound its spring, or a clock with its weights rolled down, dying as a flower dies —its merely ceasing to exist would not necessarily excite any painful feeling or regret, especially if its death made room for a successor in the bloom of youth, and destined to go through the same series of happy and painless changes. A creature born into existence in Time has no injustice

done to it, if its life be brought to a close in time. Our own immortality is not by birthright, but by the gift of God.

But when we see a noble, beautiful animal, this moment exulting in the possession of life and strength, and drinking in with keenest zest the air and light of heaven, and the next a 'kneaded clod,' the feeling natural to us is one of surprise and disappointment, like that with which we should witness a magnificent steam-engine, or other exquisitely-constructed machine, suddenly broken to pieces whilst executing its movements.

Every one must have felt, in slaying even a noxious, still more an innocent animal, that it was a harsh thing and a sad one to take away its life—a thing we cannot restore. Othello, besides the deeper reasons for lamenting Desdemona's death, grudged sorely the mere extinction of her beautiful animal existence, and contrasts the impossibility of reviving it with the power he had of rekindling an extinguished flame :—

> 'Put out the light, and then put out the light.
> If I quench thee, thou flaming minister,
> I can again thy former light restore,
> Should I repent me ;—but once put out Thy light,
> Thou cunning'st pattern of excelling Nature,
> I know not where is that Promethean heat
> That can thy light relume.'

When this, to appearance, wanton destruction of animal life occurs not once, but many times, and is seen overtaking thousands of creatures simultaneously, and that throughout the whole period of time during which, so far as we know, life has shown itself on the globe, the conceptions we had formed of material nature as a harmoniously adjusted system before we took cognizance of this fact, must be qualified as soon as we become aware of its ex-

istence; and either we must confess that the harmony we had assumed to exist, is liable to great and violent interruptions, or acknowledge that we must find, if that be possible, a new and perhaps unattainable standard of harmony, which shall include, and find a place for what was irreducible to the former one.

We refer at present, it will be observed, to death, not as implying pain or suffering, but simply as being in many, indeed in most cases, the sudden and unexpected stoppage of a machine, which, but for extrinsic interference, would have continued to perform its functions for a much longer period, perhaps for ever. The Bridgewater anatomist and physiologist have undertaken to prove to us that each animal is a wondrous self-sustaining piece of living mechanism, which, if not interfered with, shall, by imperceptible gradations, bring its movements to a close, and still itself to rest. The Bridgewater chemist has engaged to demonstrate that the vital steam which makes the living engine go, shall ever be supplied; that the fuel that evolves the steam, the air that burns the fuel, and the oil that lubricates the hinges, shall constantly be forthcoming, and anatomist, physiologist, and chemist together have exclaimed, as did Belshazzar's courtiers of old, O king!—O animal! 'live for ever,' when Death's spectral fingers on the wall write, 'Mene, Mene,' and the life that was to be so abiding, in one moment is gone.

It must, we think, be acknowledged, that as the sudden blotting out, or extinction, of one of the planets of our system would appal and terrify us, so the extinction in its prime of even a single animal, still more of several, would, and does amaze us. It throws a dark shadow over the delight with which we had witnessed the happy movements and abounding life of the joyous creature, to see it cut off

prematurely, with deep capacities of enjoyment unsatisfied, and a thousand desires unfulfilled. All the evidence previously brought forward in proof of benevolent design, and all the conviction thereby induced of beneficent purpose, only make the mystery and the sorrow the greater. When a crazy old hulk, often patched and mended, and long leaking through every seam, at length becomes water-logged and swamped in some sluggish canal, we mourn little over its loss; but when a 'President' steam-ship, with its gigantic engine beating like a great heart, its mighty paddles like revolving limbs, its fire-throat breathing forth smoke and flames, its wing-like sails, its busy crew, and gay and gallant company of seafarers, founders in mid ocean, who can find words for his sorrow? No sophistry, we think, of ingenious, one-sided advocates can alter this feeling. A watch, to take the famous Paley example, was made to go, to be wound up and to wind down; not to be broken to pieces. An animal appears made to exist through various phases, and finally to bring peacefully its motions to a close; not to have its life suddenly taken away, and its movements abruptly arrested.

In one way only can our feeling of grief at the failure of benevolent design be removed or appeased—namely, by evidence being adduced to show, that some higher and more comprehensive scheme of love than the one we have assumed to regulate this world, demanded the apparently non-benevolent, we will not say the malevolent, interferences which have so perplexed us. Whether any such higher scheme can wholly or in part be discovered, we shall presently consider.

Before doing so, however, it is necessary to discuss a question much more difficult, in reference to the subject before us, than the one the consideration of which we have

just adjourned. Death, which is not necessarily unbenevolent, not only reigns over organic nature, but something shows itself, far more anomalous in a happy world—namely, pain ; and where violent death and pain go together, and are constantly manifesting themselves, the anomaly reaches its height. It awakens, and must awaken, the saddest feelings, to consider that pain appeared in this world as soon as animal life did, and that they have reigned side by side, ministering to each other and to death, not only since man was placed on the globe, but for untold centuries before.

We take this as our second example of physical evil. Death, we have seen, tramples out and defaces design. We are now to consider pain, which mocks and distorts it. It comes within the sphere of chemistry to discuss even pain, for perhaps the greatest cause of its infliction is the slaughter of one animal for food by another, and the science we are specially discussing, is perplexed to account for such an arrangement, since, according to the results of chemical analysis, carnivorous animals might have been fed otherwise than by living on their herbivorous companions.

We have already referred to the evidence which geology supplies, of Death having triumphed throughout the early epochs of this earth's existence. The leaves of her stone book, however, have written on them, not merely records of death, but likewise of pain. The fossil fishes which abound in many of our strata, are not found stretched out in the postures of repose, which they would have assumed had they perished calmly, but like men who die in battle, with agony upon them, their bodies are thrown into violent contortions. Each has petrified its last convulsions, and, like the Laocoon and the Dying Gladiator, shows its mortal throes sculptured in stone.

These immortal agonizing statues are not strange, solitary

figures. We gaze with wonder at the world-famous Elgin marbles of the British Museum, and sympathize with the expressive looks of agony which the fighting Centaurs and Lapithæ have worn for ages. Whatever else be observed in these beautiful works of art, he who runs may read in them a plain tale of combat and strife, a struggle for life and death, mortal blows struck, pain relentlessly inflicted, and weakness giving way before the superior strength which unsparingly smites it down. When we tear ourselves reluctantly away from these wondrous sculptures, and pass to the Geological Hall in the same museum, another set of friezes appears, older by ages, perhaps by millions of years, than those of the Parthenon; carved by a chisel far excelling that of Phidias; telling of creatures, stranger even than centaurs, and of battles more terrible than those that have been fighting in marble for centuries between these monsters and their human foes; different as everything else is, the story, however, is the same.

The heroes of the geological bas-reliefs are ichthyosaurs, plesiosaurs, and pterodactyles, lizard-birds, gigantic crocodiles, strangely compounded and Titanic Gorgons, and chimeras dire, such as we thought could be witnessed only in nightmare dreams, till with forms more hideous than eye had seen, or ear heard of, or it had entered into the heart to conceive, we gaze on their stone effigies before us. In their lifetime, those strange beings were all of them warriors. The mortar-cap, the chiselled chain-shirt, and cross-hilted sword of a recumbent monumental figure, do not more plainly tell that below lie the bones of a soldier crusader, than the fierce jaws, great rows of dagger-like teeth, cruel fangs, sharp claws, and other accoutrements of those stone mummies, proclaim that their possessors were the Black Hussars of the pre-Adamite world, and gave no

quarter. The Parthenon figures only repeat the story of the Gorgon Frieze; in the latter we as plainly read as in the former, battle and murder, strength remorselessly vanquishing weakness, and the victim reaching death through the appointed stages of torture and agony.

This tale of suffering, like those dark legends which are found in every country, is repeated all over the globe. Wherever the geologist digs, he finds pain 'graven on the rock for ever.' A museum of fossil-bones is like the arsenal of a warlike nation. Weapons of destruction, teeth, claws, and horns, the swords, daggers, and spears of life militant, far outnumber toothless jaws and inoffensive mouths, the reaping-hooks and plough-shares of the peaceful herbivora.

We have referred to past, rather than to present evidences of pain, because for one thing it stands out from everything else, when taken in connexion with creatures which had not that minister of woe to them, man, to involve them in misery; because for another, the problem is every way more simple; because also, it shows that animal suffering is older than human happiness; and, lastly, because it proves what we wish to insist on in the face of all attempts to gloss the fact over—viz., that physical suffering, in relation to the lower animals, is no incidental, transient, or, as it were, interpolated thing, but that, historically, it is ingrained, and inseparably interwoven, into the whole fabric of our system.

But if we have not referred to the present, it has not assuredly been because suffering has become a dim legend, traceable only in obscure geological hieroglyphics, hidden, as it were purposely, from us in the dark recesses of the earth.

To avoid complication of the question, and the considera-

tion of the topics with which physical science cannot deal, let us put man and his sufferings aside, and look only at the lower animals, and their agonies. And as our space is limited, let a single case be selected, in evidence that pain is no forgotten pre-Adamite thing, but makes the whole creation groan and travail even now. We ask the Bridgewater natural theologian, who talks only of beneficent design, to reconcile with that beneficence this one fact, that there are myriads of animals which live only by destroying and devouring their fellows. Astronomers are familiar with a problem of great difficulty, called that of three bodies, which requires determination of the question, how will three of the heavenly bodies act and re-act on each other, in influencing and disturbing their several motions? We shall not propose so difficult a question to our Bridgewater author, but be content with requesting, at his hand, a solution of a problem of *two* bodies. It shall be this: given a carnivorous animal and the defenceless creature which it devours—to reconcile the suffering and death of the latter, with benevolence on the part of the Creator. Our problem-solver shall not escape, as he generally does, by discussing animals singly, dwelling upon the contrivances for its welfare which each animal exhibits in the construction of its parts, and stopping there. We acknowledge that a lamb is, *per se*, as benevolently fashioned as a lion; but taken together, we ask demonstration of benevolence caring for both. If we let the lion live, he will slay the lamb. If we take away the lamb, the lion will die. The two animals are, in the language of medical prescription, incompatibles; like an acid and an alkali, they cannot exist together.

If God, as revealed in nature, be, as Professor Fownes tells us he is, 'a being of *unmixed* benevolence,' what is to be made of this phenomenon? It is not an exception which

proves the rule, but in regard to a great number of animals, the rule which has no exception. It is not by accident, or incidentally, that a beast of prey kills: he was made to destroy. If any one doubt this, let him study the construction of one of the carnivorous animals. We shall not propose for consideration the lion, for he has a poetical credit for magnanimity, which might enlist the imagination in his favour, nor the beautiful tiger, nor the sun-loving eagle. Let us take an animal low in the scale of organization, and to which, therefore, nature might be expected to be more niggard of contrivances for its welfare, than she is to nobler creatures; and let it be one which no poet invests with imaginary virtue, nor any one regards with other feelings than those of horror. Let our example of a carnivorous animal be the shark. No author of 'Bridgewater Treatises,' or Actonian Prize Essayist, need ask a better evidence of beneficent design, so far as the individual animal is concerned, than the construction of the shark supplies. Its body is fashioned so as to offer the least resistance to the water through which it is to cleave its way, and enable it to move forward with a maximum velocity. Great as we are as a maritime nation, the accumulated skill of many generations has not taught us to build a vessel which can equal, or come near to, the shark in speeding through the sea. We have experimental squadrons on the waters, and read every day of one ship not being able to sail with the wind, and of another not being able to beat up against it; of one failing in reefing, and another in tacking; of all being faulty in some way. Our steam-ships are constantly being taken down, to have their engines altered, their masts lengthened or shortened; their whole equipments constructed on new, but, as it often proves, on still more erroneous principles than before. Our experimental squad-

rons must be objects of rare diversion to the fishes in the sea. Millions of millions of sharks have swum in the ocean, but no one has ever needed to be taken down to have his engine or heart shifted further forward or further back, or has required his paddles or screw-propellers, his fins or tail, to be adjusted at a new angle. No one of them ever misses stays, or goes upon a lee shore, or wrecks upon a rocky coast; but each, without compass or chart, sextant or chronometer, lunar or solar observations, is his own helmsman and stoker, pilot and engineer, and his little living yacht leaves men-of-war behind it, and can give distance to a Transatlantic steamer, and beat her in the race.

God has been very kind to the shark. Swiftness will not serve his prey to escape from the swifter fins which wing his pursuer, like a fiery-poisoned arrow, to strike through the heart of his victim. The keen nostrils of the destroyer 'scent the prey from afar,' and conduct him, with unerring certainty, through great tracts of sea, to the ship where the invalid, near to death, will soon reward him for his waiting. His great eyes are much more beautiful, in some respects, than our own. At the back of each, is a brilliant reflecting mirror, so that in the depths of the gloomy ocean, the faintest ray of light can be turned to account, and nothing but utter darkness can hide from him his prey. His teeth, in triple rows, keen-edged, like scimitars, stand like the spikes of a portcullis on his cruel jaws, and one snap of them will lop a limb away. Would our Actonian Essayist like to be the prey of this beneficently-constructed animal, or seek to taste its tender mercies? Would he be willing to thrust his limbs into the shark's jaws, and find in his mutilation and agony an evidence of unmixed benevolence?

God disowns all these pretences to prove him the author

of indiscriminate benevolence. The young lions roar to him for their prey, and seek their meat from God, and are answered as certainly as the lambs which bleat gently for green pastures. To the one as well as to the other he gives its meat in due season. 'His tender mercies are over all his works.' Physical science has affected to prove what even revelation does not profess to demonstrate—viz., that God shows himself to his creatures as an indiscriminately benevolent Being. God does not. 'He maketh darkness his secret place; his pavilion around him are dark waters, and thick clouds of the skies.' 'His ways are not our ways, nor his thoughts our thoughts.'

Pain is no transient, incidental, occasional thing. It has pleased God, for purposes which physical science cannot divine, to provide for its constant infliction. One animal is commanded by its instincts not only to slay, but also to torture another. The cat does not merely kill the mouse, but is permitted to delight in its agonies. As for the explanations which Bridgewater and other treatises have professed to give, they need not detain us long. Some tell us that it was necessary that carnivorous animals should exist. We know not how the necessity can be established. The flesh of the lion is identical with that of the lamb; there is not the slightest difference between them. The scriptural declaration that 'all flesh is grass,' admits of the most literal chemical interpretation. The edible plants on which herbivorous animals feed, contain not merely the elements of their bodies, but their very substance. Muscular flesh and fat, red blood, milk, and wheat-flour are the same bodies with their particles differently arranged. All that is in the one is in the other. The plant, as has been beautifully said, acts towards the animal as the hewer does to the builder—it supplies the animal with carved stones and chi-

selled materials, which the latter appropriates as it finds, and builds in to suit the scheme of its own edifice. The carnivorous animal finds nothing in the creature it devours, which it might not have derived from the vegetable food out of which the flesh of its prey was transmuted. For anything chemistry can show to the contrary, the lion might even now eat straw like the ox.

Again, we are told that but for the carnivorous destroyers, the herbivora would so accumulate as to become a nuisance. This, like the last declaration, is a mere 'darkening of counsel by words without knowledge.' Could the Almighty not have lessened the fecundity of the harmless animals, instead of increasing it, only that its fruits might be cut off violently in their very prime?—might he not have shortened the lives of the herbivora, and have brought them, after a brief and rose or butterfly-like life of happiness, gently to a close? If such modes of painlessly disposing of animals occur to *us*, how many more must be present to the counsels of the almighty, all-knowing God!

Lastly, some have told us that the physical scheme we are under, is such as to secure the greatest happiness to the greatest number of living creatures. It may be so; but no science can show that such is the case. It is a fond hope of the heart, not a believed truth of the intellect. The afflicted patriarch of Uz exclaimed of old, 'O that my grief were thoroughly weighed, and my calamity laid in the balances together;' but scales in which such things could be weighed were not to be found in Job's days, and are still wanting in ours. Chemistry is, of all the sciences, the one that most frequently uses the balance. She can weigh many things, but is not able to put suffering in one scale and happiness in the other, and to pronounce that the latter outweighs the former. Pain cannot be expressed by sym-

bols, or agony reduced to formulæ. And even if science could show a preponderance of happiness, we should still, constituted as we are, murmur that the greatest happiness to the greatest number, did not signify unalloyed happiness to all.

Chemistry, then, shows a dark as well as a bright side, when appealed to by the natural theologian. The first example we have selected is a positive one: it exhibits Nature deliberately poisoning whole races of animals at once. The second is a negative, but not less instructive one: it shows Nature not availing herself of the resources of chemistry to maintain life without the infliction of pain, but preferring to make animal existence dependent on suffering and death.

It is a great defect in the works of Dr. Prout and Professor Fownes, that examples of physical evil, such as we have supplied, are not furnished, or taken into consideration, in their discussion of the argument for design. Thoughtful young men, struggling to attain right views of God, who will be the most earnest readers of these and similar volumes, may be delighted with their science, but will soon perceive the one-sidedness of the view maintained. It is the 'evil that is in the world,' not the good, that perplexes us; and we rise with something like a sense of a wrong having been done us, from books which, instead of helping us to an understanding or explanation of that evil, quietly ignore it, as if non-existent or non-important, and boldly insist on our declaring that 'all is very good.' Natural and revealed religion are alike exposed to contempt by such treatment of the former, and the disappointed and provoked student is driven to the somewhat excusable, but unjust conclusion, that natural theology cannot in any satisfactory way dispose of the evil that perplexes its discussions, and is in consequence compelled to thrust it out of sight. Those who

come to this conclusion, often cease to put faith in the argument from design at all.

It is in treatises on the physical sciences that the defect we are lamenting is most liable to occur ; for psychology and ethics cannot possibly be discussed without compelling the consideration of evil as well as good ; but pleasant, readable, and most instructive volumes may be written on any one of the physical sciences, in its theological aspect, which shall, nevertheless, cleverly evade almost the mention, much more the discussion, of the real or apparent failure of beneficent design.

We long to see physico-theology treated in another way. It would set many an anxious mind so far at least at rest, to know that science honestly and deliberately acknowledged the existence of evil, even though it left it an utterly unexplained mystery.

We cannot here enter into a discussion of what physical science can do in the way of solving the enigma. We desire only for the present to turn the attention of the students of physics to the dark, as well as to the bright side of nature, and to crave them to offer us their views on the former, as well as on the latter. Nevertheless, a word may be added, for the sake of our readers, as to the bearing which the existence of physical evil has on the cogency of the argument from design for a beneficent God.

The co-existence in this world of life and happiness with suffering and death, leads directly to two questions—Do animal happiness and animal suffering flow from the same source ? Is an evil as well as a good being at work in the world ?

In ancient times, and in different countries, a sect existed, known best to us by the title of Manicheans, who held that an evil as well as a benevolent power had a share in the

control of all things on this earth. By those holding such a view, all the evil would be referred to the Caco-demon, or malignant agent, and all the good to the Agatho-demon, or good being. The Indian, Persian, Egyptian, and later Alexandrian schools were full of this doctrine. The greatest men of antiquity, however, held no such view, but referred the evil and the good to one source, counting the former either a result of the necessary imperfections of the world-system, or acknowledging it to be a mystery inexplicable. We refer to such opinions, because we think it is very difficult for us, who consciously, or unconsciously, have had all our notions of God modified by what we have learned of Him from the Bible, to be certain what conclusion we should have come to, if we had not enjoyed the benefits of a direct revelation. We are certain, however, that science lends no support to a Manichean doctrine. The evil and the good in nature are inextricably intertwined, and cannot be unravelled or disentangled from each other. What is evil in one aspect is good in another, and the two must be taken together, and dealt with as a whole.

We have no apprehension, accordingly, that the deepest study of any of the physical sciences will lead to the conclusion that this earth exhibits the results of divided counsels, or that such a lesson will ever be taught, as that the happiness of the lower animals is an expression of God's will, and their sufferings the contrivance of some antagonistic evil demon. All science, we believe, will, with increasing distinctness, join in proclaiming, with Revelation, that 'the earth is the Lord's, and the fulness thereof.' It will then only remain for science to make the fullest proclamation that evil exists, and the frankest confession that she cannot account for it. A dark reality is often more tolerable than a grievous doubt; a hopeless mystery disturbs the spirit less

than a difficult, though quite soluble, problem. There are many excellent people afraid, in the face of our natural theologies, to say that physical evil exists, lest they should be thought to impeach God's goodness, and yet troubled by the conviction that evil there is. Let such be emancipated from their bondage, by hearing the student of physical science *ex cathedra* declare that in this world there is 'shade' as well as 'sunshine;' and for those who never could be cheated into the belief that evil was not, or was good, and who stand astonished at its existence, let there be reply also. So long as men look upon the origin, and existence of moral or physical evil as a problem which can be solved by logic, they will struggle to the very death to reach the solution; but when they discover that in this world a solution of the difficulty cannot be attained, they will cease to combat with it, and transfer it from the region of the intellect to that of the heart, as a sad and solemn mystery which, with closed lips, will haunt them to their graves.

Let such hear science acknowledge, that if Plato and Socrates, Aristotle and Galen, could find no plummet able to reach the depth of the mystery of the existence of evil, Newton, Laplace, Herschel, Dalton, or Davy, have not been able to add one inch to the fathom-line, or make it go deeper. They may then, after looking the existent evil in the face till they cease to fear it, perceive that it does not swallow up the good or reduce it to zero, but simply disturbs and perplexes it; but whether they reach this conclusion or not, let the truth be plainly spoken and acknowledgment frankly made, that after all our natural theologies and prize essays, our eight commissioned Bridgewater Treatises, and ninth volunteered one, physical science must acknowledge that suffering is an enigma which she

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cannot unriddle. Chemistry, for example, can prove that God is light, but not that 'in him is no darkness at all;' she can show that God *has* love, but not that he *is* love. Before that can be demonstrated to us, to borrow a beautiful idea of Bacon's, we must pass from Vulcan to Minerva; we must turn our backs upon physics and upon all human science, and gaze in another direction, ere we shall be able to affirm that 'the darkness is past, and the true light shineth,' or comfort ourselves with the assurance that 'life and immortality are brought to light.' The mystery of pain will haunt our whole lives, and will probably never be felt so keenly as when we are tasting the bitterness of death, and are about for ever to exchange the pangs of this life for the unknown conditions of the life to come. Meanwhile, we are certain that God's benevolence is as infinite as his other attributes, and cannot doubt that some great purpose is served by the suffering of innocent animals. It may yet be given to us to know what it is. And even in this world, all who believe in revelation may contemplate with a joyous eye the good that is in it, and adjourn the explanation of the evil as something traversing, but not neutralizing or annihilating its opposite. Suffering and death may veil, but do not blot out an all-merciful God from our view. The curtain is thick, but light shines through, and words of hope are uttered to all who have ears to hear them. 'Be still, and know that I am God.' 'I form the light, and create darkness.' 'I make peace, and create evil.' 'I have created the waster to destroy.' 'I will swallow up death in victory.'

THE CHEMISTRY OF THE STARS

AN ARGUMENT TOUCHING THE STARS AND THEIR INHABITANTS.

MACAULAY'S *History of England* is now in its fifth edition; Layard's *Nineveh* is in its third; and within a few weeks of the second edition of Sir John Herschel's *Astronomy*,[1] it was out of print, and a new issue, equivalent to a third edition, is now on sale. So large a demand as these successive editions imply, is a silent but most striking tribute to the interest of the subjects discussed in those works, and the skill of the writers who have handled them. A reviewer may, in these circumstances, safely take for granted that, instead of entering into a critical analysis of works, already judged and approved by his and their readers, he may profitably make them the occasion of an excursus into regions of speculation, which such volumes have rendered patent to all. We propose to do so on the present occasion with Sir John Herschel's delightful work. It does

[1] (1.) *The Stars and the Earth, or Thoughts upon Space, Time, and Eternity.* 1847. London. Baillière.

(2.) *Outlines of Astronomy.* By Sir John F. W. Herschel, Bart., K.H., etc. etc. Second Edition. London: Longman, 1849.

(3.) *Reports on American Meteorites.* By Charles Upham Shepard, M.D., Professor of Chemistry, South Carolina, etc. 1848. New Haven, U. S., Hamlen.

not call for formal praise. The younger Herschel occupies the first rank among astronomers. He is second only to Humboldt in extensive and minute acquaintance with all the physical sciences, and is his equal in wide general culture and fine taste, and in skill as a writer. This is so well known, and so fully appreciated, that we say no more on the subject, but quote at once a passage from Sir John's preface, which will justify the use which we make of his work, and serve as a text for the present remarks :—

'If proof were wanted of the inexhaustible fertility of astronomical science in points of novelty and interest, it would suffice to adduce the addition to the list of members of our system of no less than eight new planets and satellites during the preparation of these sheets for the press.'[1]

From the inexhaustibly fertile field here referred to, we select one point for consideration, and invite our readers, for a brief space, to the discussion of an argument touching the nature of the stars and their inhabitants.

To prevent any misconception as to the scope of what follows, we wish it to be understood at the very outset, that we shall enter into no discussion as to the probability or improbability of the heavenly bodies being inhabited. We shall take for granted that they possess inhabitants, or rather shall put the question thus: 'If the stars are inhabited, is it probable that the dwellers on them resemble those on this star, or Earth, or is it more likely that they are non-terrestrial beings, unlike us, and our plant and animal companions, and different in different stars?'

We are not anxious to compel the conclusion, that all the stars are inhabited. Many of the excellent of the earth have held that they universally are, and that, too, by rational creatures; and have thought that the denial of this did in-

[1] Herschel's *Astronomy*, p. 8.

justice to our own convictions, and to the omnipotence and bounty of God. But our standard of Utilitarianism can never be a safe one by which to estimate the works of Him whose ways are not as our ways, nor does it require the view supposed.

It would not be a painful, but a pleasant thing, surely, to learn that some of the stars, such as the new planet Flora, were great gardens, like Eden of old before Adam was created; gardens of God, consecrated entirely to vegetable life, where foot of man or beast had never trod, nor wing of bird or insect fanned the breeze; where the trees never crackled before the pioneer's torch, nor rang with the woodman's axe, but *every* flower was

> 'Born to blush unseen,
> And waste its sweetness on the desert air.'

Neither is it the remembrance of the Arabian Nights, nor thought of Aladdin's lamp, that makes us add that we should rejoice to learn that there was such a thing as an otherwise uninhabited star, peopled solely by magnificent crystals. What a grand thing a world would be, containing, though it contained nothing else, columns of rock-crystal like icebergs, and mountains of purple amethyst, domes of rubies, pinnacles and cliffs of emeralds and diamonds, and gates and foundations of precious stones, such as John saw in the Holy Jerusalem descending out of heaven! All who reach the Happy Land are to enter heaven as little children, and it may please God, besides other methods of instruction, to teach his little ones his greatness and his power, by showing them such a world as we have imagined.

And even if some heavenly messenger, 'Gabriel that stands in the presence of God,' or one of the other angels that excel in strength, should descend amongst us, and pro-

claim, 'There is no life of any kind in any star but the earth,' should we be entitled to murmur at the news? Such is the pride and selfishness of man, that he does not hesitate to proclaim any world a desert, from which himself or his fellows are excluded. But even if it should be certain that every star but the earth is a ball of lifeless granite, or barren lava, it would be for us, if we were wise, to say of it, as the Psalmist would have said, 'Whither shall I go from thy Spirit? or whither shall I flee from thy presence?' In the most deserted and solitary of worlds, as we might call it, God is present. The fulness of him that filleth all in all, fills it; the Saviour and the Holy Spirit are there. If our ears were not stopped like the deaf adder's, we should, if visitants of such an orb, hear a voice say, 'Put off thy shoes from off thy feet, for the place whereon thou standest is holy ground.' We leave, then, the question of the universal habitation of the heavenly bodies untouched, and intend, moreover, to refer chiefly to the nature of the stars, and not to that of their inhabitants. The character or quality of the dwellers in the heavenly bodies is, doubtless, a more generally attractive topic than that of their habitations, as most thoughtful men would consider a forlorn and degraded savage a more truly interesting object than the grandest palace. Our only hope, however, in the meanwhile, of ascertaining anything concerning the dwellers in the stars, is founded upon what we discover concerning the stars themselves.

The direction in which our argument must proceed may be stated in a word. If we made out a rude structure on the summit of a cliff, to have all the characters of an eagle's nest, we should fairly enough infer that its inhabitants were, or had been, eagles; if we were satisfied that another erection was a beaver's dam, we should judge that beavers dwelt

within. A bee-hive would imply bees; a burrow, foxes; a mole-hill, moles; and so, if, among the heavenly bodies, we discover stars identical with our earth, we may pretty safely infer that they are, or may be, or may have been, inhabited by beings like ourselves. Direct observations on the dwellers in the stars, if dwellers there be, it is not likely we shall ever succeed in making. Of the inhabitants of the sun we shall probably never know more, than that the apostle John saw in vision an angel in it; and as for the nearest of the heavenly bodies, we may be thankful that in early life, we saw with our own eyes, as the reader knows he did, *the* man in the moon, as it is not likely that any of us who have reached maturer years shall ever see him again. Isaac Taylor thinks that our sun 'may be a world of bliss, the abode of creatures endowed with incorruptibility and immutability;' in a word, Heaven. Others, whose names we are glad to leave in oblivion, have looked upon the sun as the world of woe. John Foster thought that its inhabitants might be 'square, orbicular,' or, as he shrewdly adds, 'of any other form.' We are not about to emulate these authors. The question we shall try to answer is the much simpler one,—'Are the stars and their inhabitants terrestrial or non-terrestrial, earthly or non-earthly?'

Great men have held it probable that the stars are terrestrial in nature,—*i.e.*, fashioned of the same materials, and generally constructed like the earth. Sir Isaac Newton was of this opinion. So, to some extent, were Laplace and the elder Herschel. Humboldt has adopted it, and Mülder, the distinguished chemist of Holland. Isaac Taylor, in his *Physical Theory of Another Life*, has enlarged upon it with characteristic ingenuity and eloquence. It has been widely brought before the public by Professor Nichol, and the author of the *Vestiges of the Natural*

History of Creation, and thus it has become a subject of popular interest.

The question may at first sight appear to be one which, however attractive to the unscientific, cannot be pronounced upon by them; and such certainly is its character. Yet it may be curious to inquire what the decision of the general public is likely to be on a subject so alluring to unreined speculation; and it has been strongly held by certain of the advocates of the telluric or terrestrial nature of the heavenly bodies, that the untutored perception of analogy, and the unaided common sense of mankind, would justify the conclusion which they favour. Nay, it has been urged that the prejudices of the more lettered and scientific portion of the public incline them to prefer the theory of a non-terrestrial chemistry, although it is difficult to see how this can be the case. To satisfy all parties, however, we shall in the first place try, if possible, to learn what the so-called common sense verdict is, or rather would be; and as we can appeal to no existing document as formally recording it, we shall suppose a jury impanelled to try the question of the chemical identity of our globe and the sidereal universe.

All Fellows of colleges and of royal societies shall be excluded: all doctors of all kinds, all professors, lecturers, and the teaching class: all clergymen, lawyers, naval and military officers, civil engineers, and in general every man who puts a title before, or prints letters after his name. All critics, reviewers, writers of books, and every one else professionally or systematically connected with scientific or with literary polemics, shall likewise be protested against; and whosoever, moreover, can be shown, on the faintest suspicion, to have made science, however slightly, a matter of study. From the residue of mankind, after the roll has thus been purged, twelve honest men and true shall be chosen,

as strongly gifted with common sense as can be found. These shall form our grand jury. The case shall be tried on successive midnights, in the open court of heaven, and the cause shall be argued according to a precedent supplied by Napoleon, though not to be found in the Napoleon Code. When the First Consul crossed the Mediterranean on his Egyptian expedition, he carried with him a cohort of *savans*, who ultimately did good service in many ways. Among them, however, as might be expected at that era, were not a few philosophers of the Voltaire-Diderot school. Napoleon, for his own instruction and amusement on shipboard, encouraged disputation among these gentlemen; and on one occasion they undertook to show, and, according to their own account, *did* demonstrate, by infallible logic and metaphysic, that there is no God. Bonaparte, who hated all idealogists, abstract reasoners, and logical demonstrators, no matter what they were demonstrating, would not fence with these subtle dialecticians, but had them immediately on deck, and, pointing to the stars in the clear sky, replied, by way of counter-argument, 'Very good, messieurs! but who made all these?'

We shall judge this case in the same way. The stars themselves shall be appealed to for a reply to the question we are curious to have answered. They shall appear at the bar, and learn that a charge has been preferred against them, that 'they are of the earth earthy.' The question shall be put to each, 'Earthly or not earthly?' and the jury shall give their verdict according to the answer returned. Our twelve honest men, then, having sworn in the presence of the great Judge to give a righteous verdict, shall be taken to the summit of some heaven-kissing hill, and left there as long as they please, to make acquaintance with the stars. Far away from anxious author and captious critic, they

shall read for themselves the lesson of the universe. The heavens shall declare the glory of God : the firmament show his handiwork. Day unto day shall utter speech in their hearing : night unto night show knowledge before them. They shall watch the guiding of Arcturus and his sons : and behold the bands of Orion : they shall feel the sweet influences of the Pleiades, and listen to the morning stars singing together. 'The Sirian star, that maketh the summer deadly,' shall shine forth before them on the forehead of the sky, and they shall hearken to the solemn tread of the host of heaven, as, drawn up in their constellations, they nightly repeat their sentinel march from horizon to horizon.

And when the unsatisfied senses are still filled with desire, all needful help shall be furnished to gratify their longing. The Herschel forty-feet telescope shall be granted our jury to gaze through, and the courteous Lord Rosse will not refuse the giant reflector. Pulkowa, and Altona, and the Cape shall lend the best instruments of their observatories, and the ingenious Lassell shall record for them what he witnesses with his space-piercing tube. The wise and filial Herschel shall stand by to explain ; and the eloquent Arago and sweet-tongued Humboldt make the wayfaring man, though a stranger, at home in the universe. As witnesses, however, witnesses only, shall these high priests of nature be called, and speak to facts, but offer no opinions.

Our twelve shall first cast a glance at our own solar system, and observe that no one of its planets has the same magnitude, inclination of axis, so far as that has been observed, density, time of rotation, or arrangement of orbit ; but that each, in nearly all these particulars, differs greatly from its brethren. They shall notice that several of the

planets have no moons: that our Earth has one relatively very large one: Jupiter, four relatively small ones: Saturn, seven of greatly varying dimensions: Uranus, as is believed, six; and Neptune, two or more. They shall see the splendid girdles which Saturn wears, and be warned that two at least of the moons of Uranus move from east to west, or in a direction opposite to that of their planet, and of all the other bodies of the solar system.

The enormous differences in the length of the planetary years shall startle them; that of Mercury, for example, being equal to about three of our months; that of Neptune, to 164 of our years. The lesser but marked diversities in the length of their days shall awaken notice, the Mercurial day being, like our own, twenty-four hours long, the Saturnine only ten. The variations in the amount of heat and light received from the sun by each of its attendants shall not be forgotten; Uranus, for example, obtaining two thousand times less than Mercury, which receives seven times more than the Earth. They shall also observe the extent to which the planets are subject to changes of season; the Earth knowing its four grateful vicissitudes; Jupiter knowing none; whilst the winter in Saturn, under the shadow of his rings, is fifteen years long. All those unresembling particulars shall be made manifest to our observant twelve. Neither shall they be forgetful of those dissimilarities in relation to atmosphere, and perhaps to physical constitution, which astronomers have detected. When so much diversity has been seen to shine through the unity of the solar system, our twelve shall gaze forth into space, to see if all be sameness there. Sameness! They shall discern stars of the first magnitude, stars of the second magnitude, of the third, of the fourth, of the seventh, down to points so small, even to the greatest telescopes, that the soberest of philoso-

phers can devise no better name for them than star-dust; and one of them declares 'that for anything experience has hitherto taught us, the number of the stars may be really infinite, in the only sense in which we can assign a meaning to the word.' They shall find that the Dog-star is a sun, whose light has an intrinsic splendour sixty-three times greater than that of our own solar orb, and that he is not counted chief of the stars. They shall search in vain through the abysses for a system similar to our own, and find none, but perceive instead, multitudes of double-stars or twin suns, revolving round each other. They shall learn that there are triple systems of suns, and that there may be more complex ones; and try to conceive how unlike our planetary arrangements must be the economy of the worlds to which these luminaries furnish light. They shall gaze at purple and orange suns, at blue and green and yellow and red ones; and become aware of double systems where the one twin appears to be a self-luminous sun, and the other a dark sphere of corresponding magnitude, like a sun gone out, as if modern science would assign an exact meaning to Origen's reference to 'stars, which ray down darkness.' Herschel shall show them the sidereal clusters, many of which 'convey the complete idea of a globular space filled full of stars [*i.e.* suns] insulated in the heavens, and constituting in itself a family or society apart from the rest, and subject only to its own internal laws.' Lord Rosse shall exhibit the nebulæ, resolved and unresolved. The continental observatories shall furnish records of those strange heavenly bodies which periodically wax and wane, now shining like 'candles of the Lord,' now darkening with Ichabod on their foreheads. Tycho Brahe shall tell of those mysterious unabiding stars, which have flashed almost in a moment into existence in the heavens, and have died

away like all precocious things prematurely, appearing as if to verify the poet's prediction, that the sun himself will prove a transient meteor in the sky. The Chinese astronomers shall proclaim the paths of ancient comets, which neither Greek nor Roman had courage or science enough to trace through the heavens; and Humboldt, after describing the wanderings of the comets of later days, shall supply the commentary that so great are the differences among these eccentric bodies, 'that the description of one can only be applied with much caution to another.' The American observers shall detail how thick and fast the 'fiery tears' fall from the November meteors: and a thousand other witnesses stand ready to affirm 'of diversity there is no end.' But we may suppose our somewhat distracted twelve, at this stage of the proceedings, to decline further evidence, and bethink themselves what their verdict shall be.

'These stars!' one juryman will say—a chandler we may guess, or oil-merchant, or perhaps only a lamp-lighter—'these stars! these suns! "these street lamps," as Carlyle has called them, "in the city of God," are they to be counted, my brethren, so many argand-burners, each cast in the same mould, with wick clipped to the same length, and fed with the like modicum of oil, that it may spread an equal number of rays over the same square section of heaven's pavement? Nay! are we not certain that at least they differ in size and brightness? and if thus they vary in dimensions and in splendour, as well as in colour of light and in mode of arrangement, is it likeliest that in other respects they differ only in degree, and have all but one function, or that they differ in kind and in office also? Some shall be likened to fragrant wax-candles, lighting up gay drawing-rooms; and others shall be murky torches following the dead to the tomb; and others, Eddystone lamps

saving goodly ships from destruction ; and others, rainbow-tinted vases, making the streets gay on coronation festivals : or strontia-fires, bidding armies begin battle ; or Bude flames, illuminating halls of parliament ; or lime-ball and electric lights on lofty mountain-tops, measuring arcs of the globe.'

A second of the twelve shall arise, a blacksmith, or stoker, by the look of him. 'That visible sun of ours, it should seem, is the open furnace-door of a great locomotive engine, sweeping through space. Its train goes with it, of Jupiter-Saturn first-class carriages, Mars-Earthly second class, and Ceres-Vesta third ones ; satellite trucks being here and there interspersed through the train ; and comet engines provided to go special messages. Those far distant stars, it should seem, are locomotives too, and like enough, propel planet-trains, though no one has seen even traces of the latter. But are we free to settle that each drags its Jupiter, its Earth and Vesta carriages behind it, with the same lord and squire passengers in the first, citizens well-to-do in the second, and stout mechanics or ragged Irishmen in the third ? Are the paint and lacquer, the cushions and the paddings, the door-handles and the wheels, and all the similar coach furniture, to be looked for in these hypothetical trains, exactly as they are found in our sun's planet-carriages ? Let us consider before we admit this, how many coupled engines we see ; how many triplets and other locomotive wonders, which are likely to have attendants as strange as their engines, and pause before we settle that space is but a railway network, traversed by up and down trains, differing only in length and speed, and carrying in the same vehicles the same kind of passengers and goods, at the one Universal penny a mile.

'It seems, indeed, but an appeal to our ignorance to say,

that that Sirius-engine, for example, differs nothing from our Sun-locomotive but in size. Its fire is far brighter and hotter than ours, and perhaps as much because it burns a different sort of fuel, as because it merely burns more of the same coke that our locomotive consumes. Neither does it seem a self-evident proposition that the Sirian machine must be made up of some sixty chemical pieces, because one of the carriages of our Sun's train consists of so many. And as for the train of the Dog-star, if there be one, it appears not unlikely that the traffic of the regions through which it runs may be very different from that of our zodiac, and that the vehicles composing the suite of Sirius may differ in many particulars from such as accompany our Sun. I, for one at least, will say that I perceive no grounds for assuming that where diversity prevails in relation to all the points that are cognizable by us, sameness should be counted to be the rule in regard to everything that is hidden from our sight.'

A third juryman, who has plainly served before the mast, will make bold to ask the question—'Those ships of heaven that go sailing past, each on its mysterious God-commissioned errand, were it wisest to consider them a fleet of herring-boats or collier brigs, some larger, some smaller, but all built of the same materials, rigged in the same style, and carrying the same cargo? Or were it wiser to compare ourselves to the watchers on lonely Ascension Isle or solitary St. Helena, now signalling a man of war with its "Mariners of England;" then an African slaver with its doleful passengers and demon-crew; now a heavy-laden Indiaman rich with the wealth of China; then a battered South Sea whaler, filled with the spoils of slaughtered monsters of the deep; light Tahitian schooners with cocoa-nuts and arrow-root; stout American ships with ice

for the epicures in India; English barks, with missionaries for the heathens of all lands. Oak ships, and teak ships, and ships hammered out of iron; sailing vessels, and ocean steamers with paddles and screw-propellers. Danes, Dutchmen, and Swedes, Frenchmen, Russians, and Spaniards, each with its different build, its unlike dialect, its strange flag and unresembling crew. All sizes and shapes and kinds of navigable craft, with all sorts of unimaginable cargoes and motley companies of sea-faring men.

'If there are all these differences among our sailing vessels, are there likely to be fewer among the ships of heaven? Do you think it probable that if by means of some loudest speaking-trumpet, we could hail each shining orb with "Star ahoy!" and thereafter, by means of some farthest echoing reverberating hearing-horn, could get back an answer, that from every one would be returned the same doleful or trivial earthly murmur—*Californian Diggings; Kaffre War; Ministers Outvoted; Fête at Paris; Insurrection in China; His Holiness the Pope's last Bull.*

'My friends, think of this. In the azure sea above us, there are no shores or landing-places; it is one boundless PACIFIC OCEAN, where the frailest bark never hides behind a bulwark, or drops anchor in a storm. The fleets of heaven are all phantom ships, for ever sailing, but never nearing port. If they are all then as nearly as possible identical, why are there so many? If the nature and object of each is the same, why are they not pieced together so as to make up one huge vessel? They might as well have been nailed and hammered into a single mighty sun, or sun-earth, lighting up, and darkening itself, while it floated through space, like a gigantic Noah's ark, laden with every living creature.'

This is our sailor-juryman's opinion; but we have an

old serjeant also among our twelve, and he claims to be heard next. 'The skipper,' he begins, 'the skipper has likened the stars to men-of-war, and so will I, though in a different sense from him, but with a view to repeat his question: If the celestial bodies are all alike, why are there so many of them? The stars, I have been told, are the "Host of Heaven," "the armies of the sky," and if so, are something more than a regiment, and are likely to present other differences than merely a grenadier company of stars of the first magnitude; a light company of stars of the second; a mass of troops of the line, of the third; and drummer-boys of the fourth. An army, my friends, is not a *row* of pipe-clayed men, with stiff stocks and buttoned gaiters, turning their eyes to the right or the left as some martinet colonel gives the word of command. It counts not by men but by companies, not by companies but by regiments, not by regiments but by battalions, not by battalions but by nations. Its officers are dukes and archdukes, kings and emperors. It has cavalry and infantry, artillery battalions, rifle brigades, rocket companies, engineers, sappers and miners. In that small matter of arms and clothing how endless the difference! Plumed bonnet, helmet and shako, grenadier cap, cocked hat; plaid, cuirass, hussar-jacket, broadsword, sabre and spear, bayonet, pistol, carabine and musket: all kinds of dress and equipment, and every variety of weapon, worn by all sorts and conditions of men. And if man, bent only on fighting for his hearth and home, and without caring for diversity, nay, doing his best to provide against it, by "tailor's uniform," "serjeant's drill," "pipe-clay," "orders of service," and whatever else promised to smooth over differences,—has never been able to do more than iron straight and make uniform a single regiment at a time, and that for the shortest period,

how is it likely to be with that Host of Heaven as ye call them ? Scarcely among earthly hosts has some latest regulation-cap become comfortable on the head of its military wearer, before he who planted it there to realize his thirst for unity, has grown weary of its sameness, and must have the felt shaped anew. This is the lesson that nature has taught him, how not two leaves can be found alike, not even two peas : and if not two alike, still less three : least of all thirty or a thousand. If, moreover, among objects of the same class or species every additional unit shows an additional difference, how much greater the probability of variety, when there is a likelihood of the individuals belonging to different tribes ! Call not, then, the heavenly bodies a host, or army ; or at least acknowledge that they must have mighty differences among them. I say not that each "sentinel star" is unlike all others. It is enough if it be unlike many. There may be whole battalions of the same race, wielding the same weapon, and wearing the same uniform : but will this be the case with the entire army ? It was not so with Pharaoh's host, or the Roman legions, with Attila's hordes or Britain's army, or with any host that man has seen. I ask no other evidence of diversity existing among the starry night-watchers than that there are millions of millions of them. Such numbers do not exhaust unity ; no numbers can ; but they exclude sameness when oneness of species cannot be shown ; and before we have counted even our thousands, "all things," I doubt not, "will have become new." Yes ! the falchion that Orion wields is forged of a different metal from the flaming sword of the comet, or the fiery weapon of Mars, and the club of Hercules is carved of another wood than the shaft of Bootes' spear.'

A long-haired, ample-collared young gentleman, will here interrupt our *militaire* :—'Of regimental tailoring and

army cutlery I know nothing. But did not Byron write that immortal line,—

> "Ye stars! which are the poetry of heaven;"

and what think ye did he mean by that? That our sun, with the help of his family, had once since the beginning of things composed an ode; he, after much thought, giving out the first line, his planets with difficulty furnishing a line a piece, the moons attending to the stops, whilst the comets supplied the interjections and notes of admiration. His lordship, too, would intend us to understand, either that copies of this remarkable production were handed round the universe, or that, by a striking coincidence of genius, such as happened more than once to himself and Goethe, each sun with due help composed once in its existence the very same family piece; so that for millions of centuries the stars have all been chanting like the children of an infant-school, the same unchanging, meagre version of "the hand that made us is divine."

'That might be his lordship's meaning: but might he not, perhaps, intend us to understand something very different, and expect to have our sympathy with another view of things? Our earth, I think, alone engages to furnish a whole epic of "Paradise Lost," through "Man's first disobedience, and the fruit of that forbidden tree," and each sphere it is likely has, like Thalaba, its wild and wondrous tale to tell. The poetry of heaven, according to my Lord Byron, or any other of the poet guild, is no solitary sonnet, or single song, but an Olympic contest of Iliads and Odysseys, epics and lyrics, tragedies and comedies, histories in twenty-four books, isolated verses, single hymns, detached odes, and separate songs, where the same poem is never recited twice by one author, nor similar compositions made

public by different poets; but in endless diversity, a countless succession of abounding rhymes flows on, of "grave and gay, and lively and severe," recounting the history and the destinies of the universe, and glorifying him who sits enthroned as its King.'

'Ay! and the music of the spheres,' will a sweet-tongued juryman say; 'is that some unaccompanied melody; some "Gloria Patri" of three notes; or "God save the King" upon a single string, played endlessly upon the millions of similar barrel organs that make up the universe? or is the latter some grandest cathedral organ provided not merely with "*vox humana*," or earthly stops, but with unnumbered Phœbus flutes, martial trumpets, Aries horns, serpent clarions, and pedals touched by the feet of him who walketh on the wings of the wind? Under the vault of heaven it stands a complete orchestra, now with muted voice, as the fingers of God move over one starry bank of keys, lisping under breath some simple melody, then, as they change to another, sounding out a trumpet obligato, or "when the Highest gives his voice," rolling forth with open diapason a "Jupiter symphony," or guiding the Hallelujah chorus of the morning stars singing together. The starry choir, I ween, is no African row of monotonous performers singing in unison, and able to sing only one song, but a Russian horn-band, where each individual furnishes his indispensable single, and unlike note, towards the universal harmony, and the troop can execute all kinds of music: or a German festival-chorus with its thousand voices, and its unlike parts undulating together into one vast symphony, and flowing on as a mighty river of sound. "There is no speech nor language where their voice is not heard. Their line is gone out through all the earth, and their words to the end of the world."'

The chancellor, or foreman, however, of our twelve, desiring impartiality, and also, as befits his office, loving unity, shall here interpose :—' My friends, let not this discerning of diversity prevail with us too far. From the evidence laid before us it should seem, that this solar system of ours is a goodly branch, on the summit of whose stem blooms a brilliant sunflower, whilst round its stalk, at due distances, are arranged the components of its foliage, some twenty broad planet-leaves, and about as many moon-leaflets. Besides these, there are myriads of sharp-pointed, swift-piercing, straggling comet-thorns, which have occasioned much annoyance to those who have handled them. With these I shall not meddle ; but those far-distant, non-planetary stars ! were it not good to count them sunflowers also, of which on some branches indeed there are two on one stalk, and on others three ; larger it may be in certain cases, and fairer than ours, purer in their tints, and varied occasionally in the hue of their petals, but sunflowers all of them, and embosomed in more or fewer leaves and leaflets like those on our own stem ? It were no mean and paltry idea of a universe, or meagre scheme of its unity, to compare its clustered stars to unfading flowers blossoming on the branches of one great tree. I should liken it to such a monarch of the wood as Nebuchadnezzar beheld in his night-dream, or, better, to such as Ezekiel saw in waking vision. " A cedar in Lebanon with fair branches, and with a shadowing shroud, and of an high stature ; and his top was among the thick boughs. . . . . All the fowls of heaven made their nests in his boughs, and under his branches did all the beasts of the field bring forth their young, and under his shadow dwelt all great nations. . . . The cedars in the garden of God could not hide him : the fir-trees were not like his boughs, and the chestnut-trees

were not like his branches; nor any tree in the garden of God was like unto him in his beauty."'

'Yes!' one will reply, 'that truly were a goodly scheme, and a grand unity, but were it not a better thought, productive of a grander unity, and as likely to be the true one, that that starry universe is no one flowered cedar unvaried in its beauty, but such a tree of life as the Daniel and Ezekiel of the New Testament, the beloved apostle, saw, which bare "*twelve* manner of fruits," and "whose leaves were for the healing of the nations?"'

'And were it not,' a third will say, 'grandest still, and most likely, that that midnight sky shows us no Lebanon with its single cedar, however stately, nor any one tree, however different its flowers, but a whole "Garden of God," with its oaks, and its elms, and its fir-trees; its myrtles and its roses: ay, and its lilies of the valley, its daisies and violets too? Yes! stars are like stars, as flowers are like flowers, but they do not resemble each other as roses do roses, or lilies lilies; but as the rose does the lily, or the dark violet the star-eyed daisy.'

Our Chancellor, caught like Absalom in the branches of his own metaphor, shall say no more on the matter in dispute, but content himself with pressing for a conclusion. And thereupon the twelve, various in their unity, shall stand up with uncovered heads in the stillness of night, and lift their unanimous voices to heaven. 'By Thee only, Judge of all the earth, and all the universe, can this cause be decided, and to the judgment of Thy supreme court do we refer it for final issue. But, in the meanwhile, we are free to give our verdict according to the evidence laid before us, and it runs thus:—

'"*There are celestial bodies, and bodies terrestrial; but the glory of the celestial is one, and the glory of the terrestrial is*

'*another. There is one glory of the sun, and another glory of the moon, and another glory of the stars: star differeth from star in glory.*" ' To which verdict, we, for our part, understanding the words in their widest sense, will append our heartiest Amen.

The 'fulness of him that filleth all in all' is of its essence inexhaustible, as we perhaps best realize when all metaphor is set aside, and we reflect on the one quality that belongs to God's attributes: namely, that they are Infinite. It is part of his kindness to us, that he never lets us lose sight of this great prerogative of his nature, but, alike by suns and by atoms, teaches us that his power and his wisdom have no bounds.

It cannot be that he reveals himself otherwise in the oceans of space. Were we privileged to set sail among the shining archipelagos and starry islands that fill these seas, we should search like marvelling but adoring children for wonder upon wonder, and feel a cold chill of utter disappointment if the widest diversity did not everywhere prevail. The sense of Unity is an over-ruling power which never lays aside the sceptre, and will not be disobeyed. We should not fear that it would fade away, nay, we know that it would stand forth mightiest when its kingdom seemed to have sunk under overwhelming diversity. Unity is in nature often nearest us exactly when variety seems to have put it farthest away. We are like the sailors of Magellan who first rounded the globe. Every day they sailed farther, as *they* reckoned, from the place of their departure, and ploughed what seemed to *them* a *straight* line of increasing length, which had all to be retraced before their first harbour could be gained: but, behold, when they had sailed longest, and seemed farthest from home, they had the least to sail over, and were nearest to port. Ex-

actly when hope of return was faintest, were they called on to exclaim, like the Ancient Mariner—

> ‘Oh, dream of joy! is this indeed
> The lighthouse top I see?
> Is this the hill? is this the kirk?
> Is this my own countree?’

A voyage through space would in like manner turn out to be a circumnavigation. We should set sail from Unity, and traverse the great circle of a universe's variety, till we came round to Unity again. The words on our lips, as we dropped anchor, would be, ‘There are differences of administrations, but the same Lord; and there are diversities of operations, but it is the same God which worketh all in all.’

Our readers may be disposed to think, that in all that has been said we have evasively begged the question. A phantom-jury of men, professedly unlettered, but in reality bearing the same relation to the majority of the different classes they represent, that the pedlar of Wordsworth's ‘Excursion’ does to ordinary pedlars, have disposed of the problem under discussion, apparently unanimously enough. But if their verdict were submitted to the revision of a tribunal of men of science, it may be thought doubtful whether it would be ratified. Let us transfer, then, the question of the terrestrial or non-terrestrial character of the heavenly bodies, from the ‘outer court of the Gentiles,’ in which we have hitherto heard it argued, to the ‘inner court of the priests,’ even of the high-priests of Nature, who serve at her altar, the philosophers properly so called. Our space will not permit us to put on record the judgments of all of them, but we may find room to chronicle the opinions of three of the priestly dignitaries, the Astronomer, the Chemist, and the Physiologist, or Biologist.

A quotation from Sir John Herschel will show the judgment of Astronomy on the question we are discussing, so far as the planets are concerned.

'Three features principally strike us as necessarily productive of extraordinary diversity in the provisions by which, if they be, like our earth, inhabited, animal life must be supported. These are, *first*, the difference in their respective supplies of light and heat from the sun; *secondly*, the differences in the intensities of the gravitating forces which must subsist at their surfaces, or the different ratios which on their several globes the *inertiæ* of bodies must bear to their *weights*; and, *thirdly*, *the difference in the nature of the materials of which*, *from what we know of their mean density*, *we have every reason to believe they consist.*'[1]

The two first points of diversity noted, refer to differences in the *intensity* of certain influences, which, however, we shall presently find are, of themselves, sufficient to make terrestrial life, as we see it, impossible upon at least the majority of the planets. The third is a most explicit reference to a difference in the kind of materials of which the several planets consist, which their difference in density betrays. 'The density of Saturn,' for example, 'hardly exceeds one-eighth of the mean density of the Earth, so that it must consist of materials not much heavier than cork.'

We shall refer to this question more particularly presently, when discussing the testimony of chemistry as to the components of the spheres.

Direct telescopic observation, moreover, has also supplied the astronomer with some information concerning the physical constitution of the heavenly bodies, the chief points of which we condense here, mainly from Herschel's minute

[1] *Outlines of Astronomy*, p. 310.

descriptions of the characteristic features of each of the members of the solar system.

So far as the sun is concerned, it may suffice our present purpose to say, that nothing certain is known regarding its constitution. It is supposed to have a kind of triple atmosphere, one portion of which is luminous; the second consists of highly reflective clouds, which float below the first, and throw off its light and heat; the third is a mass of gaseous matter, believed to include the luminous and cloudy portions, and to envelop the solid sphere of the sun. In what condition the last is, either as to temperature or to illumination, is quite uncertain; nor is anything known in relation to its composition. Observations, however, on the transit of Venus over the sun's disc, have enabled astronomers to infer that the sun has not an atmosphere of the same nature as that of the earth; and this may be said to be the only matter tolerably certain concerning solar chemistry. Mercury is too near the sun, Uranus and Neptune too distant from it; Vesta, Ceres, Juno, Pallas, and the other minor planets, too small to permit observations as to the condition of their surfaces. Venus is thought to have an atmosphere, and some have conceived they saw hills on its disc, but the existence of these is doubtful. Mars most resembles the Earth of all the planets. The outlines of what are considered continents are very distinct, and what seem to be seas are equally visible. The polar regions, too, present appearances strongly favouring the idea, that snow or ice is collected at them, thawing in the martial summer, and becoming more abundant in its winter. This is by far the most interesting fact, as in truth it is the only positive one, so far as we know, which the telescope has supplied in relation to planetary chemistry. To have good reasons for suspecting that so characteristic

and important an earthly ingredient as water occurs in Mars, is assuredly a matter of great interest. The more abundant element of that fluid (oxygen) is also the most important constituent of air, and may perhaps exist free around the planet. A globe which had water, and an oxygen atmosphere, might certainly put in some chemical claim to be a sister of the earth. But such speculation is premature. The presence of water does not justify the inference that free oxygen is also existent; nor does it warrant the conclusion that more than fifty other elements must be there also. It may further be noticed that the atmosphere of Mars is less distinct and abundant, and much less opaque and cloudy, than we should have expected in the case of a planet thought to possess a great body of water. Astronomers, however, appear to be by no means agreed, either as to the nature or to the extent of the martial atmosphere. Some deny that there is one at all.

The strange fiery-red light of this star, also, implies a peculiar condition of its whole uncovered surface, very unlike what our earth's exterior exhibits, and forbids any conclusion as to the general identity of their superficial condition or component ingredients. It still more forbids rash inferences as to terrestrial plants and animals existing on a body of unknown composition.

Nothing is known concerning the surface of Jupiter, which his cloudy atmosphere conceals from inspection; but observations on the eclipses of his moons have shown that that atmosphere does not sensibly refract light. It therefore differs from that of the Earth; but we have at present no means of ascertaining what its constituents are. The disc of Saturn is also hidden from us by a gaseous or vaporous covering, the nature of which is unknown. His rings are perhaps naked, but they are rarely objects of full

telescopic observation, and the state of their surfaces has not been minutely described.

The Earth's satellite is the only moon which has been carefully examined; and we can say more concerning its superficial condition than that of any other of the heavenly bodies. It is the least terrestrial, to appearance, of them all. The moon has no atmosphere, no air, no clouds, no rain, nor dew, nor lakes, nor rivers, nor seas! It has great plains and valleys, but to appearance, barren as the Sahara, for the lunar seasons produce no change on them; nor have traces of vegetable or animal life been detected on any part of its unfruitful surface. It has gigantic mountains, nearly every one an active or extinct volcano, with craters of enormous depth; but their summits and edges, relieved from the wearing and disintegrating action of air and water, and unclothed with verdure, are in all cases rugged and sharp, unlike the worn, or covered, and everywhere rounded outlines of our hills. To this astronomical description of the moon we add the remark, that there is something altogether non-terrestrial in the existence of myriads of gigantic volcanic craters, without an atmosphere floating round the sphere containing them, or water existing at its surface; for all the active earthly volcanoes pour out volumes of steam and other vapours and gases, which would soon reclothe our globe with an atmosphere, if it were deprived of its present one.

It does not appear, then, that the telescope favours the idea that a telluric or terrestrial character is common to the members of the solar system. On the other hand, at the sun, the moon, and Jupiter, it brings into view phenomena, which, so far as we can observe them, are so marked and peculiar, as to imply a state of their surfaces quite unlike that of our planet. To the consideration of this we shall

return more fully, when referring to the judgment of Biology on the Stars as theatres of Life. Meanwhile, we proceed to inquire what decision Chemistry gives on the problem before us. It is to this part of the discussion that we are most anxious to direct the reader's attention, not because it is intrinsically more important than the points already gone over, but because of its comparative novelty, and the erroneous interpretation which has been put upon it.

It might seem, at first sight, as if chemistry could have nothing to say on the matter : yet for ages she has hankered after an alliance with astronomy, and has chronicled the fact in her nomenclature. The alchemist was an astro-chemist, and twin-brother to the astrologer. Gold was Sol ; silver, Luna ; iron, Mars ; lead, Saturn, etc. ; and we still speak of lunar caustic, and of martial and saturnine preparations, when referring to certain of the medicinal compounds of silver, iron, and lead. One of the most important of the metals every day reminds us, by its name, Mercury, of the affinity which was once thought to connect it with its namesake, the planet. The astrologist, however, long ago became an astronomer, and the alchemist a chemist ; and for a lengthened period they had no dealings together. It has been otherwise latterly. The extension of both sciences has led to their meeting again, and this in a somewhat singular way.

His own little Juan Fernandez island of an earth, was apparently the only spot in the universe of which the chemist could declare, 'I am monarch of all I survey.' Towards the far-distant stars, however, he cast wistful eyes. They were almost all suns, the astronomer told him, which for ages had evolved light and heat, and spread them through space. Can chemistry, then, which for centuries has been explaining—always more and more success-

fully—the evolution of heat and light on this earth, give no information concerning their production at the sun? It seems that perhaps it may. When a ray of sunlight is passed through a prism, certain 'fixed lines' or dark spaces are seen in the resulting spectrum, unlike those which the spectra of terrestrial flames exhibit. Sirius and Castor, as well as other stars, exhibit peculiar spectra also. 'Now a very recent discovery of Sir D. Brewster,' as Professor Graham observes, 'has given to these observations an entirely chemical character. He has found that the white light of ordinary flames requires merely to be sent through a certain gaseous medium (nitrous acid vapour), to acquire more than a thousand dark lines in its spectrum. He is hence led to infer, that it is the presence of certain gases in the atmosphere of the sun which occasions the observed deficiencies in the solar spectrum. We may thus have it yet in our power to study the nature of the combustion which lights up the suns of other systems.'

Such is one example of the way in which chemistry has sought to extend her dominion into space. Another is furnished by the conclusions which Wollaston drew as to the quality of the atmospheres of the sun and of Jupiter, from the absence in them of power to refract light sensibly, as shown in the case of the sun, during the transits of Venus, and in that of Jupiter when his moons are eclipsed by him. It has recently, however, been found possible to apply chemical analysis directly to certain of the heavenly bodies, so that, without extravagance, we can now declare that there is a chemistry of the stars as well as of the earth.

The oft-quoted Oriental proverb, which teaches, that since the 'mountain will not come to Mahomet, Mahomet must go to the mountain,' has, in this case, for once, been reversed; for when the chemist could find no way of

travelling to the spheres, behold ! certain bright particular stars have come to him and submitted to analysis. We refer to the aërolites, meteorites, or meteoric stones, which, according to the most generally adopted of many theories, at one time were thought to have been projected from volcanoes in the moon. They are now almost universally acknowledged to have been true stars before they reached our earth. For a statement of the reasons which have led astronomers to this conclusion, we must refer our readers to Humboldt's *Cosmos*, where the whole subject is discussed at great length. It may suffice to say, that many considerations justify the conclusion, that multitudes of asteroids, starlets, or as Sir John Herschel calls them, 'meteor-planets,' revolve in definite orbits round the sun, and some also as invisible, or momentarily visible, minute moons round the earth. The orbits of some of the former are believed to resemble that of the earth, but to be in a different plane, so that in the course of their revolutions round the sun, these tiny planets come, at certain periods, within the sphere of the earth's attraction, and are precipitated as meteoric stones upon its surface, as weary and forlorn birds of passage, far out at sea, are entangled in the rigging of vessels, and fall helpless on deck.

This modern theory of meteorites reads like a bald rendering of the poetical myth of the angels, whom earthly loves induced to forfeit for ever their places in the heavens, but it has invested the strange fallen stars, to which it refers, with a new interest. The largest of them is but a microscopic grain of the star-dust scattered over the sky, but it is none the less of celestial origin, and may be submitted to analysis.

The meteorites have accordingly been put upon the rack by the chemist, and all their secrets have been tortured out

of them, but they have revealed fewer marvels than at one time was expected. No new chemical element or primary ingredient has been found in any of them. In other words, they contain no ultimate chemical component which the earth does not contain. This remarkable fact has seemed to many to justify the belief, that other worlds have been constructed out of the same materials as our own. It is thus, for example, turned to account by the author of the *Vestiges of the Natural History of Creation.* After stating that the elements, or simplest chemical constituents of the globe, are those sixty or more substances which have hitherto resisted all attempts to reduce them to simpler forms of matter, he proceeds thus :[1]—

'Analogy would lead us to conclude that the modifications of the primordial matter forming our so-called elements, are as universal, or as liable to take place everywhere, as are the laws of gravitation and centrifugal force. We must therefore presume that the gases, the metals, the earths, and other simple substances (besides whatever more of which we have no acquaintance), exist, or are liable to come into existence under proper conditions, as well in the Astral system, which is thirty-five thousand times more distant than Sirius, as within the bounds of our own solar system, or our own globe.'[2]

We leave unnoticed, till we proceed with our discussion, the assumption contained in the passage just quoted, that the earth, considered as an aggregate of chemical substances, is a type of the chemistry of the universe. It is thus justified by a reference to the meteoric stones :—

[1] The exact number of chemical elements, or simple bodies, is uncertain, as recent researches still incomplete have revealed the existence of several whose chemical relations have not yet been fully ascertained. We use the integer 60 as sufficiently near the true number for our present purpose.

[2] *Vestiges of the Natural History of Creation*, Fifth Edition, p. 30.

'What is exceedingly remarkable, and particularly worthy of notice as strengthening the argument that all the members of the solar system, and perhaps of other systems, have a similar constitution, no new elements are found in these bodies [meteorites]; *they contain the ordinary materials of the earth*, but associated in a manner altogether new, and unlike anything known in terrestrial mineralogy.'[1]

The clause of this sentence, which we have marked by italics, contrives, by an unwarrantable concealment, to convey a very false impression of the true nature of meteoric stones. They are said to 'contain the ordinary materials of the earth,' which no doubt they do; but it should have been added, that they contain only *some* of them; so far as we know, but the smaller part.

We have not on record a great number of analyses of meteoric stones, for they are comparatively rare; it would be premature, therefore, to decide that we know all their constituents. But so far as our knowledge extends, it does not appear that a third of our earthly elements has been found in these bodies. Humboldt, in his *Cosmos*, quoting from Rammelsberg, the greatest living authority on the subject, enumerates only eighteen of the sixty elements as occurring in them. Professor Shepard counts nineteen as certain, and adds two more as doubtful. It is to be observed, on the other hand, that not only are the majority of the terrestrial elements, including many of the most important among them, totally wanting from meteoric stones, but those which are present are not mingled (as the quotation indeed acknowledges) in earthly proportions.

Our globe consists, speaking generally, of two opposite classes of ingredients,—namely, metals and non-metallic bodies, some of which, as oxygen in the one division, and

[1] *Vestiges of the Natural History of Creation*, Fifth Edition, p. 42.

the precious metals in the other, occur free, but the greater number in combination with some body or bodies of the unlike class. There are many more *kinds* of metals than of non-metallic substances, but the latter, taken as a whole, occur in much larger *quantities* than the former. One non-metallic body alone, oxygen, is computed to form a third of the weight of the crust of the earth. In meteoric stones, on the other hand, whilst non-metallic elements are the less numerous constituents (only a half of those occurring in the earth being found in them), they also occur in much smaller quantities than the metals. Of some of them, indeed, traces only are found.

Many of the best-marked aërolites are masses of nearly pure metal, chiefly iron, with a small proportion of nickel. Others contain cobalt, manganese, chromium, copper, and other metals, diffused through them in minute quantities, associated with a small percentage of oxygen, sulphur, chlorine, etc. The stony meteorites consist chiefly of silica and metallic oxides.

Whilst thus, meteoric stones contain only a portion of the elements of the earth, that portion is made up (in the greater number of meteorites), so far as the relative quantities of its components are concerned, almost entirely of metals. A meteoric stone represents, therefore, only a third of the whole constituents of the earth so far as *number* is concerned, and except to a small extent, but one class of them so far as *nature*. A globe so constituted could never, by any process of development (unless its so-called elements suffered transmutation), become possessed of water, or an atmosphere, or give birth to terrestrial plants or animals.

It may make the matter clearer to those not minutely conversant with chemistry, who may suspect us of hypercriticism, if we illustrate the force of our argument thus.

The conclusion in which we are asked to acquiesce is this strange one, that an aggregate of nineteen, or at the utmost twenty-one ingredients, is the same thing as an aggregate of sixty.[1] According to this view, a double flageolet of two tubes should be the same thing as a pan-pipe of seven, or an organ with scores of them; and a village fife and drum should be identical with a full military band, because the latter includes a fife and drum. It should thus make no difference whether one inherited an iceberg or a green island, Tierra del Fuego or the gold district in California; for the iceberg possesses *to the extent of its possession* (namely, so much ice or solid water) what the fertile island contains, and Tierra del Fuego is rich, to the extent of its riches, in the wealth of California.

Perhaps, however, we are dealing in a misleading exaggeration. The ingredients missing from the meteor-planets may be properly enough marked by the minute analyst as absent, and yet be of no great consequence in reference to the suitableness of the latter to become theatres of life. The difference between the meteorite and the earth is perhaps only such as existed between Paganini's fiddle with one string, and Thalberg's piano with some hundred, from both of which instruments the same melody might sound. If such be the case, the author of the *Vestiges* could have no objection to allow us to place him within the receiver of an air-pump, and deprive him of only one of the sixty ingredients—namely, oxygen—which is absent from many of the meteoric stones. Only twenty-one elements, it should seem, are needed, and we have been kinder to him

[1] Twenty-one is the aggregate number of chemical elements found in meteoric stones, but no one meteorite contains so many. Some of the best known consist almost entirely of one ingredient. We state the case, therefore, in the way most disadvantageous for our argument when we speak of the meteoric elements as twenty-one in number.

than he is on paper to himself, for we have allowed him fifty-nine. Why does he pant so? and gasp for breath? Oxygen, it should seem, is no needless superfluity or choice luxury. The lung was not made to breathe without the breath of life being provided for it; and a meteoric stone, as our author, before being let out of our receiver, shall confess, would be as fatal as a vacuum to every terrestrial creature. Let it be further noticed that the missing elements of the meteoric stone are exactly those which are most abundant in plants and animals, and the worth of our author's reasoning will appear; but to this we shall return.

The chemical argument stripped of all exaggeration, stands thus. Several specimens of the bodies of space have been subjected to analysis—namely, the earth, so far as its crust or accessible portion is concerned, and meteoric stones. The latter have not a common chemical composition, but are divisible into sections, each of which represents a separate example of planetary chemistry.[1] When the meteorites and the earth are compared, they are found to differ immensely, so far as the mode of arrangement, the relative quantities, the number and nature of their constituents are concerned. Here, then, are several unlike chemical specimens of the universe. To which among them are the other heavenly bodies to be compared? Analysis has succeeded in making one step beyond this earth, and has immediately brought to light a non-terrestrial chemistry. If it could stride on to sun, moon, and stars, what should it find? Different chemistries? or that of the earth or the meteoric stones endlessly repeated? Different chemistries, we think, and this for many reasons.

[1] Professor Shepard divides meteorites into two classes—*Metallic* and *Stony*; and each class into three orders, under which *thirteen* sections are included.

If the heavenly bodies were constructed of the terrestrial or the meteoric chemical elements, arranged in the way these are in the earth, or in the meteorites, the densities of the heavenly bodies should, within no very wide limits, be identical with the specific gravity of the earth, or of some one of the meteoric stones; but the opposite is the fact, for the Sun, Jupiter, Saturn, Uranus, and Neptune, have all a density much below that of our planet, or of any of the meteor-planets, as the following table, where the specific gravity of the earth is made unity, will show:[1]—

Earth, 1; Sun, 0·25; Jupiter, 0·24; Uranus, 0·17;
Saturn, 0·14; Neptune, 0·23.

Apart altogether from this difference in density, it is manifest, that confining ourselves to purely chemical considerations, we could assign no satisfactory reason for preferring the earth to the meteoric stones, or the latter to the earth, as types of the chemical composition of one or all of the heavenly bodies; neither can we venture to affirm that we have exhausted in our globe and the meteor-planets the only existing examples of variation in composition which the universe presents, so that every star must be classed with the one or the other, inasmuch as they comprise all the diversities which occur in sidereal chemistry. On the other hand, it is not difficult to show that chemistry amply provides for every star having a different composition, and

[1] In the table in the text we have not given the specific gravity of any of the meteorites, because their densities vary so much, that the mean of their specific gravities does not afford a datum of any value in reference to our argument. For the satisfaction, however, of the reader, we may mention that, according to Humboldt, 'the specific weight of aërolites varies from 1·9 to 4·3. Their general density may be set down as 3, water being 1.' Humboldt's maximum is certainly too low, for various of the American meteorites, examined by Professor Shepard, have a density above 7; whilst, therefore, the earth is 5·6 times heavier than water, the densest of the meteorites are 7 times heavier, and the lightest within a tenth of being twice as heavy as water.

renders it exceedingly probable that different stars in this respect differ greatly.

In the first place, the chemical elements do not present that character of completeness and unity, considered as a great family, which we should expect in the raw material of a whole universe. When we subdivide them into groups, they arrange themselves unequally. Thus in several cases we find divisions of elements, such as chlorine, bromine, iodine; barium, strontium, calcium; niobium, pelopium, tantalum, in which the characteristic properties of each of the components of the group pass into those of its other members by the most delicate shadings. In other examples, again, although analogous properties are not wanting in related bodies, the particular substance (*e.g.*, nitrogen or mercury) stands apart, isolated as it were, and exhibiting but remote affinities to its nearest neighbours. In all science, however, and strikingly in chemistry, isolation is the exception, and association the rule. In these cases of apparent isolation, it is possible that elements which would make up a group, and connect the solitary in friendly alliance with the families about it, may exist in other worlds, as animals supplying gaps in the zoological circles are found extinct in the strata of other eras than our own. Such hypothetically deficient elements no doubt may yet be found in our own globe; but for the present, we must adopt the rule, 'de non apparentibus, et de non existentibus, eadem ratio.' Or we may find all the so-called elements to be modifications of some simpler or simplest forms or form of matter, and be able to convert that into unknown substances of the same grade as our present elements, and so satisfy the supposed need of harmony. Even if we should, however, achieve this result, it would only alter the mode of stating the problem, which would then run thus,—What

forms of the primary matter are likely to occur in different globes?

Secondly, it may be remarked that some of our terrestrial elements, such as the metals of the earths proper (except aluminum) and also selenium, tellurium, molybden, vanadium, tungsten, as well as others, are not known to be of service in our globe. It would be very rash to permit our ignorance to be the measure of a question like this. These bodies may have been, or may yet be, even if they are not at present (which, however, is only an assumption), of the utmost value in effecting necessary changes on the earth. Man, too, as his knowledge extends, may discover economical applications of the elements in question of the greatest importance. Withal, however, we may suppose that some, at least, of these substances may not have been specially destined to be of use on our globe, but may bear the same relation to it that rudimentary organs do to the bodies of the animals possessing them, so that they are of little or no service to the structure in which they occur, but are typical of much more highly developed instruments, or arrangements, in other organisms or spheres. These seemingly useless, and sparingly distributed bodies in our earth, may be the prevailing or most important constituents of other globes, and may perform functions there of which we have no conception. Other elements, such as arsenic, yield compounds so deadly to vegetable and animal life, and so apparently unserviceable in the mineral kingdom, that one is almost driven to believe that it was not primarily for us, but for some other beings in a different world, such bodies were provided. At least, we suppose there are few who will consider the slight service which arsenical preparations have rendered to medicine, or their efficacy in poisoning rats and flies, and the fact of their furnishing

certain pigments, as an equivalent for the multitude of human beings whom they have consigned to untimely graves, and the many crimes to which they have furnished temptations.

Thirdly, nature has been very niggard to us of certain of the elements, for example, of one peculiar and very valuable class, the noble or precious metals, gold, platina, palladium, rhodium, etc. We do not refer to the scarcity of these as limiting our luxury, or count them precious in the sense of being costly. Gold and platina, to mention no others, have the desirable properties of never wasting, rusting, or corroding, and platina will not melt in the heat of a blast-furnace. Were these or the allied metals more abundant, our eating, drinking, and cooking vessels would be made of one or other of them. Our steam-boilers, railroads, furnace-bars, lamp-posts, and the like, would be constructed of platina, rhodium, or palladium, and our lighter and more elegant instruments and utensils of gold, which would be too cheap to tempt thieves to steal. One may suppose that other worlds may have been more richly favoured than we are with supplies of these or other goodly bodies, which find so limited scope for exhibiting their manifold virtues here. Can platina, *e.g.*, considered as a veritable, simple substance, be supposed to have been created solely to supply the terrestrial chemist with tests and crucibles ? The chemist will probably think that a very satisfactory final cause for its creation, and we will not cry nay to it. But what if there be worlds where this metal is so abundant that they are sick of the sight of it, and would be glad to see a piece of rusty old iron, where the thieves steal the costly magnesia, and the royal crowns are made of the precious metal, lead ? To speak more soberly, is it very unlikely that so marked and striking a metal as platina, as well

as its congeners, may occur more abundantly in other worlds framed on a different ideal from ours? We have no wish, however, to try our hand at improving God's fair and beautiful world.

To sum up the matter, we observe, without insisting on more, that we have no ground for assuming that we see on this earth all the kinds of elementary, or quasi-elementary matter which can exist. Still less are we justified in affirming that we have manifested on this globe the only modes of arrangement or of distribution, so far as relative quantity is concerned, of which our elements are susceptible. The very opposite is likely to be the case. The fact of there being *many* chemical elements awakens the suspicion that they were intended to be arranged in *many* ways. Had our globe been a ball of iron, or of lead, we should have had nothing to suspect in space but iron or lead. But when there are more than sixty earthly constituents, arranged, too, in a quite arbitrary way, we cannot resist the expectation that they will be found apportioned among the celestial spheres, not in that one way, but in various ways: here a few, there many together; in one globe, bodies of one class; in another, of another; in no one, perhaps, exactly the arrangement that prevails in any of the rest. Our globe may be called a mosaic of some sixty pieces, but it has not pleased the Great Artist to make equal use of each of the sixty. Not more than a half of them can be detected except by minute inspection, and the predominating tints are only some six or seven. Other stars may be mosaics constructed out of more or fewer of the same pieces, but they are, in all probability, put together according to different patterns. Let it not be forgotten that the omission of a single element would make a great difference. A globe in all other respects identical with ours would be utterly

unfitted for being the theatre of life such as we see, if it wanted, as we have already noticed, but the one body oxygen, or hydrogen, or nitrogen, or carbon. The addition in considerable quantity of a single new potent element would equally derange the economy of a world. The arrangement in a different way, without addition or abstraction, of existing elements, would be as efficacious a cause of disturbance. If, for example, the nitrogen and oxygen of our atmosphere were suddenly to combine (and every thunderstorm occasions combination), we might be maddened by laughing-gas, or drowned in an ocean of nitric acid. The shades of variation in such a case would become shadows of most portentous depth and darkness.

If any one, indeed, will consider how many tunes can be made with the seven primary notes of music ; how many numbers can be combined out of the ten numerals ; how many words out of the twenty-six letters of the alphabet, he may conceive how enormously great is the number of worlds, each quite distinct, which could be constructed out of the sixty elements. In the first place, there is a means of variety in the *number* of the simple bodies. One globe, like our earth, contains them all. Others, like the meteoric stones, may contain only some of them. Secondly, the *relative quantities* of the elements may vary. On one globe, the abounding element may be oxygen, as in our earth ; in another platina. A third cause of variety will be the *condition* of the elements. With us, hundreds of tons of chlorine are locked up in mountains of rock salt. In other worlds, that gas may be free, and form an atmosphere like our air.

Add these modes of varying composition together, and employ them all, and where will the variety stop ? Millions of millions of worlds would not exhaust it. To what ex-

tent this susceptibility of variation has been taken advantage of by the Architect of the Heavens we cannot tell; but to suppose that it has been turned to no account seems a conception meagre beyond endurance. If we but knew the use to which the spheres are put, we might possibly hazard a conjecture concerning their composition, but of that we are altogether ignorant. Yet to suppose that the Infinite One has exhausted the counsels of his wisdom in arranging the chemistry of our globe, and could only therefore repeat that endlessly through space, or to affirm that such a monotonous arrangement of the great world or universe is in keeping with the endless diversity visible in the little one which we inhabit, is a view of things that may not be entertained for a moment.

We close this long chemical discussion with one remark. Speculation set aside, the testimony of chemistry in reference to the heavenly bodies is neither more nor less than this, that every one of them which has been submitted to analysis, differs in composition from all the rest. Absolute chemical identity of any two or more has never been observed, whilst the extremes of difference between those least like each other, if denoted on a scale, would be 60 and 1; the maximum of this scale being the earth with its sixty ingredients, the minimum, those well-known meteorites, which are little else than lumps of malleable iron. The importance of this fact has been overlooked, because, beginning with the earth, we have found the meteor-planets composed of fewer ingredients than it, and these all terrestrial.

Assuredly it would have been a more remarkable circumstance, if the meteoric elements had all been novel, and possessed of striking and unfamiliar properties; and something like disappointment has been felt because they are not.

But we must not, on this account, disregard the fact that the meteorites are non-telluric in their chemical characters. They are so, as much by the terrestrial elements they want, as they would have been by the novel elements they might have possessed. Had a single non-terrestrial element been found in a meteoric stone, our philosophers would have been lost in wonder. Yet, within the last ten years, six or seven new elements, namely, Didymium, Lanthanum, Niobium, Pelopium, Tantalum, Erbium, Terbium, have been discovered in our own planet, and none but professed chemists have paid any attention to the fact, nor has the discovery perceptibly altered any of our scientific beliefs. Had but one of those obscure metals been found in a meteorite, and in it alone, speculations would have abounded on its nature and uses. Nevertheless, the addition of six or seven such metals to our globe, by the tacit confession of all science, is of infinitely less importance to the earth, than the loss of one such element as oxygen, hydrogen, nitrogen, or carbon would be. To find, therefore, one of the latter absent, is truly a more interesting fact in relation to terrestrial chemistry, than it would be to find *all* of the recently discovered metals, or as many more similar elements, present. The most richly endowed of the meteoric stones, moreover, contain not a majority, but less than a fourth of the terrestrial elements, and of many of the most characteristically terrestrial elements, only traces. As soon as this fact is distinctly perceived, men will cease to complain that there are no new meteoric elements, and none will refuse to acknowledge that, so far as analysis has proceeded, terrestrial and sidereal chemistry are quite different.

It remains now only to consider what the judgment of Physiology or Biology is likely to be concerning the manifestation of life in the heavenly bodies. It has, to a con-

siderable extent, been anticipated or implied in what has been stated already.

Life, as it exists on this globe, is compatible only with certain conditions, which may not be overstepped without causing its annihilation. The whole of these need not be enumerated, as the failure of one is as fatal to existence as the absence of all. The three to which Sir John Herschel has referred—namely, difference in the quantity of heat and light reaching each globe; variation in the intensity of gravity at its surface; and in the quality of its component materials—may suffice to illustrate this. Light and heat are essential to the development and maintenance of earthly life, but their excess is as destructive to it as their deficiency. What, then, shall we say of the sun, whose heat we know by direct trial to be of such intensity, that after great degradation or reduction, it can still melt the most infusible minerals, and dissipate every metal in vapour; and whose light is so intolerably brilliant, 'that the most vivid flames disappear, and the most intensely ignited solids appear only as black spots on the disc of the sun, when held between it and the eye?' If the temperature of the solid sphere or body of the sun be such as those phenomena imply, it must be the abode, if inhabited at all, of beings such as Sir Thomas Browne refers to, who can 'lie immortal in the arms of fire.' It is within possibility, however, that the body of the sun is black as midnight and cold as death, so that as the eye sees all things but itself, he illuminates every sphere but his own, and is light to other stars, but darkness to his own gaze. Or the light and heat of his blazing envelope may be so tempered by the reflective clouds of his atmosphere, which throw them off into space, that an endless summer, a nightless summer-day, reigns on his globe. Such an unbroken summer, how-

ever, though pleasant to dream of, would be no boon to terrestrial creatures, to whom night is as essential as day, and darkness and rest as light and action. The probabilities are all in favour of the temperature of the sun's solid sphere being very high, nor will any reasonable hypothesis justify the belief that the economy of his system in relation to the distribution of light and heat can resemble ours.

We can assert this still more distinctly of the planets. We should be blinded with the glare and burnt up if transported to Mercury, where the sun acts as if seven times hotter than on this earth ; and we should shiver in the dark, and be frozen to death if removed to Uranus, where the sun is three hundred times colder than he is felt to be by us. To pass from Uranus to Mercury would be to undergo, in the latter, exposure to a temperature some two thousand times higher than we had experienced in the former, whilst on this earth the range of existence lies within some two hundred degrees of the Fahrenheit thermometer.

As for our satellite, Sir John Herschel says of it, 'The climate of the moon must be very extraordinary : the alternation being that of unmitigated and burning sunshine, fiercer than an equatorial noon, continued for a whole fortnight, and the keenest severity of frost, far exceeding that of our polar winters, for an equal time.' It would seem, then, that though all else were equal, the variations in amount of light and heat would alone necessitate the manifestation of a non-terrestrial life upon the sun, and the spheres which accompany the earth in its revolutions around it. All else, however, is not equal. The intensity of gravity at the surfaces of the different heavenly bodies differs enormously. At the sun it is nearly twenty-eight times greater than at the earth. 'The efficacy of muscular power to overcome weight is therefore proportionably

nearly twenty-eight times less on the sun than on the earth. An ordinary man, for example, would not only be unable to sustain his own weight on the sun, but would literally be crushed to atoms under the load.' 'Again, the intensity of gravity, or its efficacy in counteracting muscular power, and pressing animal activity, on Jupiter is nearly two and a half times that on the earth, on Mars is not more than one-half, on the moon one-sixth, and on the smaller planets probably not more than one-twentieth; giving a scale of which the extremes are in the proportion of sixty to one.'

From this account, it appears that we should be literally mercurial in Mercury, saturnine in Saturn, and anything but jovial in Jupiter, where we should be two and a half times heavier and duller than here. On the smaller planets we should feel like swimmers in the Dead Sea, or as if in a bath of quicksilver, where to sink is impossible. 'A man placed on one of them would spring with ease sixty feet high, and sustain no greater shock in his descent than he does on the earth from leaping a yard. On such planets giants might exist, and those enormous animals which on earth require the buoyant power of water to counteract their weight, might there be denizens of the land.' If the fixed stars be suns, of what ponderous adamant must the beings be fashioned which exist on their surfaces! Were it possible for us, clothed in some frigorific asbestos garment, to endure unscathed the flames of Sirius, it would only be to be crushed to powder against his enormous globe. Here, then, is a second point of diversity, of itself sufficient to forbid the development of the earth-life we see here on almost any other of the heavenly bodies.

And we do not require to enlarge upon the third point of diversity — variation in the chemical composition of the spheres. The absence of an atmosphere from the Moon,

and the peculiar characters of that of Jupiter and of the Sun, have already been referred to as forbidding the appearance of terrestrial life under their skies. The impossibility of its manifestation on meteor-planets such as have reached our earth has also been sufficiently dwelt upon.

In the face of the immense diversity which has thus been shown to prevail through space, it should seem impossible to hold the belief that the stars are all but so many Earths. The author of the *Vestiges*, however, in his blind zeal for the nebular hypothesis of a common physical origin of all worlds, and solicitous to save God the trouble of taking care of his own universe, thinks otherwise.

'We *see*,' says he, speaking as if the nebular hypothesis were an established fact, 'that matter has originally been diffused in one mass, of which the spheres are portions. Consequently, *inorganic matter must be presumed to be everywhere the same*, although probably with differences in the proportions of ingredients in different globes, and also some difference of conditions. Out of a certain number of the elements of inorganic matter are composed the elements of organic bodies, both vegetable and animal; *such must be the rule* in Jupiter and in Sirius as it is here. We are, therefore, *all but certain* that herbaceous and ligneous fibre, that flesh and blood, are the constituents of the organic beings of all those spheres which are as yet seats of life.'[1]

He proceeds a little further on to say, 'Where there is light, there will be eyes; and these, in other spheres, will be the same in all respects as the eyes of tellurian animals, with only such differences as may be necessary to accord with minor peculiarities of condition and of situation. It is,' he adds, 'but a small stretch of the argument to suppose that one conspicuous organ of a large portion of our animal

[1] *Vestiges of the Natural History of Creation*, p. 171.

kingdom being thus universal, a parity in all the other organs,—species for species, class for class, kingdom for kingdom,—is highly likely, and that thus the inhabitants of all the other globes of space have not only a general but a particular resemblance to those of our own.' [1] How baseless this reasoning is, with its 'small stretch' at the close, we need not stop to demonstrate anew, but a few words may be added, in reference to the concluding argument concerning the relation of eyes to light.

It is a hasty and unwarrantable conclusion that every illuminated globe must contain living eyes. On our own earth there are many animals without organs of vision; so that we cannot conclude that eyes are a necessary reaction of light and life upon each other. Worlds may be supplied with light for other reasons than to endow their inhabitants with the faculty of sight. Our sun is a centre of many influences. We know at least three which may be separated from each other—light, heat, and what has been called actinic or chemical force; but probably electricity and magnetism also emanate from his orb. Terrestrial plants and animals are powerfully affected by most, probably by all of those; but the inhabitants of other spheres may not have organs enabling them to take advantage of more than some, perhaps only of one of the forces in question. On the other hand, the sun may be the source of agencies of which we know nothing, which are about us and yet do not affect us, because we have no channels or senses by which they can find access to us. The dwellers in other planets may have organs of which we have no conception, enabling them to enjoy these either as substitutes for the influences which affect us, or in addition to them.

Our sun, it is true, sends light to his several planets and

[1] *Vestiges of the Natural History of Creation*, p. 172.

their moons, but that they all make the same use of it is in no degree probable. They may, some of them at least, be 'old in rayless blindness,' yet not like Schiller's Proserpine, 'aching for the gold-bright light in vain.' They may have 'knowledge at one entrance quite shut out;' but so likely enough have we, and at more entrances, perhaps, than one. The sun may impartially distribute the same gifts, though in unequal quantities, to his family; but it depends on each member of the circle what improvement is made of them. Mercury, who receives Benjamin's portion, may well be expected to show a different result from the newly-discovered, scantily-endowed Neptune, who has so long and so mysteriously tempted Uranus from his course. We would liken the different planets and satellites of our system to so many pieces of stained glass in a cathedral window; on every one, the same seven-tinted light falls, but the chemical composition, and molecular arrangement of each transparent sheet determines whether it turns to account the whole seven and gleams white, or profits only by certain of them, and shows, in consequence, green or red, blue, purple, or yellow. If some tiny fly, whose dominion was limited to the inside of a single pane, should suppose that, as its kingdom was bathed in unchanging red, every other sheet of glass must be 'vermeil tinctured' also, because it knew that on every one the same light fell, it would greatly err, as we are wise enough to know. But we who are 'crushed before the moth,' probably err as widely, if we affirm that each of the planets is a mirror reflecting the sun in the same way. He is probably like a fountain, sending forth a river charged with many dissimilar substances, and each of the planets resembles a filter, separating from the stream what its construction enables it to retain, and what was intended and is fitted to be appropriated by it.

Even, however, if we should concede to our author that wherever there is light there will be eyes, surely a few more data are necessary, before a whole animal can be assumed. Can we infer that lungs or other breathing-organs exist, unless we make it probable that there is an atmosphere to breathe? Can we take for granted wings or birds or of insects, unless we show that there is air to fan? or, may we count on the 'hearing ear' before we establish that there is a gaseous or aqueous medium to transmit the undulations of sound? If there be no water, will there be paddles of whales or of turtles, or fins of fishes? If no carbon, will there be leaf or stem of flower or tree? If no lime, bone or skeleton of any animal? The existence of all these organs cannot be assumed merely because there is light. But, in truth, as little can organs of vision. For if there be no water, there can be no blood; and if no blood, then not even eyes, at least earthly eyes, however constant and brilliant the light may be.

The unequivocal testimony, then, of physical science, as it seems to us, is against the doctrine that life, as it appears on the stars, must be terrestrial in its nature, though we are far from wishing to affirm that planets closely resembling the earth may not occur in space. It is enough for our argument to show that there are myriads of stars, which, for the reasons already given, are altogether non-terrestrial in their characters.

It remains, then, to inquire, whether we are to come to the conclusion, that the stars are uninhabited, inasmuch as terrestrial life is the only possible one, or to believe that there exists a diversified astral life which is manifested on them. Abstaining from anything like an attempt to define positively the probable characteristics of the latter, if it exists, we may say this much on the matter. There are

fewer characters of universality in terrestrial life than in terrestrial chemistry. There is a plant life and an animal life, which are quite separable, and may exist apart, and there are different kinds of each. To mention but one example: the egg of the butterfly has one life, and the caterpillar which springs from it has another; and the chrysalis into which the caterpillar changes has a third, and the butterfly which rises from the chrysalis has a fourth; and so there may be worlds which know only a germinal, or a caterpillar, a chrysalis, or a butterfly life.

Further, in this world we see plants and the lowest animals possessing only the sense of touch, if the former can be said to be endowed even with that. Gradually as we ascend in the animal scale, additional senses are manifested, till four more appear in the highest animals. But who shall tell us that these five are the only possible, or even the only existing channels of communication with the outer world? We might, besides the general argument from analogy against such a conception, refer to those agencies influencing living beings, which have been recognised for centuries as implying some supersensuous relation to external nature. It would be unwise to allow the extravagances of animal magnetism to prevent us from recognising the indications which several of its phenomena afford, of perceptions of outward things not easily referable to the operation of any of the known senses. Nevertheless, that so-called, and as yet questionable science, has, for a season at least, fallen into the hands of those with whom the gratification of wonder is a much greater object than the discovery of truth, and we fear to build much upon it. We can find, in another and quite unexceptionable quarter, a substantial foundation on which to assert the probability of life being manifested very differently in other spheres than

it is in our own globe. We refer to the assurance which the New Testament gives us, that our human spirits are destined to occupy bodies altogether unlike our present ones.

From the remarkable way in which the Apostle Paul likens the 'natural body' to a seed which is to be sown, and grow up a '.spiritual body,' one is led to believe that the immortal future tabernacle is to bear the same relation of difference, and yet of derivation to the present mortal one, which a tree does to a seed. The one will be as unlike the other as the oak is unlike the acorn, though but in a sense the expansion of it.

Whether this be the doctrine or not which the Apostle teaches, it is at least certain, that he announces that a great and inconceivable alteration is to come over our bodies. Doubtless, our spirits are to be changed also, but more, as it seems, in the way of intensification of faculties, desires, passions, and affections—on the one hand, good, on the other, evil—which have been exercised or experienced, in their fainter manifestations, in the present state of existence, than by the introduction of positively new elements into our intellectual and moral being. We do not urge this point; it is enough if it be acknowledged to be a Scripture doctrine, that human spirits, reminiscent of their past history, and conscious of their identity, are, however otherwise changed, to occupy bodies totally unlike our present ones. If, however, it be supposed that the 'spiritual' occupants of our future tabernacles are to differ totally from us, it only adds to the force of the argument, as it implies the greater diversity as to the manner in which being may manifest itself. It is part, then, of the scheme of God's universe, that spirits clothed in non-earthly bodies shall dwell in it. It is idle, therefore, to say that terrestrial life

is certainly the probable sidereal one, since it is not the only existing, or at least the only contemplated mode of being. In looking at the stars as habitations of living creatures, we have at least two unlike examples of the way in which mind and matter admit of association to choose from, as patterns of what astral life may be. But the further lesson is surely taught us, that there may exist other manifestations of life than only these two. For the spell of simplicity once broken by a single variation, we know not how many more to expect, whilst the conclusion is not to be resisted, that other variations there will be. The same Apostle who dwells on the resurrection, tells us, in reference to the happy dead, that 'eye hath not seen, nor ear heard, neither have entered into the heart of man, the things which God hath prepared for them that love him.' They are not only, therefore, to have bodily organs different from ours, but these are to be gratified by sights which our eyes have not witnessed, by sounds to which our ears have never listened, and by a perception of phenomena inconceivable by us. There are here indicated the two great elements of variety to which we have already referred; a theatre of existence totally unlike the present one, and organs of relation to it different from those of terrestrial beings.

The argument might be greatly extended, but we cannot attempt here an exhaustive discussion of the subject. The sum of the whole inquiry is this:—Astronomy declares that there are unlike theatres of existence in the heavens,—suns, moons, and planets; Chemistry demonstrates that different kinds of construction, that of the earth, and those of the meteoric stones, prevail through space; Physiology contemplates the possibility of a non-terrestrial life unfolding itself in the stars; and the Bible reveals to us, that there is an immortal heavenly, as well as a mortal earthly life.

The consideration of all this leaves no place for the thought, that the tide of life which ebbs and flows through the universe is but the undulation of so many streamlets identical with that which bathes the shores of our globe. In our Father's house are many mansions, and the Great Shepherd watches over countless flocks, and has other sheep which are not of this fold.

CHEMICAL FINAL CAUSES,

AS ILLUSTRATED BY THE PRESENCE OF PHOSPHORUS, NITROGEN, AND IRON IN THE HIGHER SENTIENT ORGANISMS.

THE recent unexampled progress of anatomy, chemistry, and physiology, has brought into startling prominence a problem which may be stated thus, 'Why do certain chemical elements or ingredients, rather than others, enter into the composition of plants and animals?' This question has probably been put to himself more or less clearly by every considerate student of the sciences named above, and has unconsciously guided researches which did not professedly deal with it. There is not one, moreover, of our great physiologists and chemists who has not long meditated on this problem, and largely contributed to its solution, but their replies, in the majority of cases, have been indirect and implicit; sometimes indeed instinctive rather than intentional; and those whom they have addressed have often failed to perceive that a question had been proposed, and an answer to it given. A very few have distinctly considered the problem, among whom a foremost place must be assigned to the learned Lehmann,[1] in whose writings such phrases as 'the physiological value' of an element

[1] *Physiological Chemistry*, by Professor G. C. Lehmann. Vol. i. Translated for the Cavendish Society by Professor G. E. Day, St. Andrews. *Methodological Introduction*, pp. 10, 25.

continually occur, and who is induced only by a sense of the complexity of the inquiry, and the hopelessness in the present state of our knowledge of disposing of its difficulties, to adjourn its discussion for a season.[1] As for the great majority, again, of educated, intelligent, medical men, and others conversant with chemistry and physiology, if such queries are addressed to them as, 'Why do our skeletons consist of bone rather than of wood, or flint, or marble? Why are our teeth composed of ivory rather than of steel? Why is our blood charged with iron rather than with gold?' they are simply startled and make no reply. And truly no reply but a most imperfect one is or ever will be possible; nor is it otherwise than with the utmost diffidence, that I attempt to suggest why only certain of the elements occur in living organisms. The question, however, is certainly one worth attempting to answer, because its consideration cannot but lead us to ennobling meditations of God, one of whose glories it is 'to conceal a thing;' whilst, to the extent that we can answer it, we shall enlarge the domain alike of the science of biology and of the art of medicine. For no one will doubt that science would gain by the disposal of the problem before us; and it is scarcely less evident that if we knew one reason, still more each of the reasons, why even one element, not to say all the organismal elements are present in our bodies, we should be better able, by the amount of that knowledge, to preserve health and to cure disease.

The problem thus awaiting a fruitful solution is as follows. Our globe, including the atmosphere, and the ocean with its tributary waters, consists in very unequal proportion of some sixty substances, which, according to our present knowledge, are simple or elementary. Of these

[1] *Op. cit.* pp. 440, 443.

sixty chemical elements, less than a third are found distributed throughout the entire vegetable and animal kingdoms. Of this fractional third, one-half occur only in small quantity, so that the *greater* part of the bulk and weight of plants and animals is made up of one-fifth or one-sixth of the whole elements; and the *greatest* part consists of but three, carbon, hydrogen, and oxygen. This will appear from the accompanying table, in which the chemical elements occurring in plants and animals are distinguished from those known to be absent from their tissues, or not yet recognised as present. The ever-present elements of plants and animals I have distinguished as *organismal*, rather than as *organic;* because on the one hand, the whole of the elements found in living structures are also found in inorganic masses; and on the other hand, many organic substances (according to the chemist's definition of such), as kakodyle, stibio-methyle, and zinc-ethyle, contain respectively arsenic, antimony, and zinc, which are not normal constituents of plants or animals, and unless in the smallest quantities, are deadly to all of them.

Organismal Elements.	Non-Organismal Elements.
Non-Metals.	
1. Oxygen.	1. Selenium ?
2. Hydrogen.	2. Boron ?
3. Nitrogen.	
4. Carbon.	
5. Sulphur.	
6. Phosphorus.	
7. Silicon.	
8. Chlorine.	
9. Bromine.	
10. Iodine.	
11. Fluorine.	

Organismal Elements.	Non-Organismal Elements.	
	Metals.	
12. Potassium.	3. Aluminum.	24. Niobium.
13. Sodium.	4. Antimony.	25. Osmium.
14. Calcium.	5. Arsenic ?	26. Palladium.
15. Magnesium.	6. Barium.	27. Pelopium.
16. Iron.	7. Bismuth.	28. Platinum.
17. Manganese.	8. Cadmium.	29. Rhodium.
	9. Cerium.	30. Ruthenium.
	10. Chromium.	31. Silver.
	11. Cobalt.	32. Strontium.
	12. Copper ?	33. Tantalum.
	13. Didymium.	34. Tellurium.
	14. Erbium.	35. Terbium.
	15. Gold.	36. Thorium.
	16. Glucinum.	37. Tin.
	17. Iridium.	38. Titanium.
	18. Lanthanium.	39. Tungsten.
	19. Lead ?	40. Uranium.
	20. Lithium.	41. Vanadium.
	21. Molybdenum.	42. Yttrium.
	22. Mercury.	43. Zinc.
	23. Nickel.	44. Zirconium.

The elements marked with a (?) are those which have either been occasionally detected in plants and animals, or which there are reasons for thinking would be found if sought for. Claims were at one time largely set up for arsenic and lead, as present in all animals in small quantities, but those claims are now generally disallowed. A similar claim, but on better grounds, has been urged in behalf of copper, which is sometimes present in the human body,

and is apparently never absent from some of the *Mollusca*, *Cephalopoda*, *Ascidiæ*, and *Crustacea*.[1]

Of the two missing non-metallic elements, Selenium, the analogue of sulphur, may be found accompanying the latter in the sulphur-compounds of the animal organism; and Boron, the salts of whose oxy-acids resemble those of carbon and silicon, may be associated with the alkaline carbonates and phosphates. Neither of these elements has as yet been sought for.

It may seem at first sight, questioning the sufficiency of the Chemist's 'victorious analysis' to detect every ingredient of a complex whole, to hint that he may have missed certain organismal elements because he did not seek for them; seeing that he professes his ability to resolve an unknown composite substance into each of its ingredients, however numerous they may be, provided only they are all among the recognised sixty (or more) elements. But in reality, the Physiological Chemist has never done more than say, '*this* is present,' and has always left a margin for those possible elements which had not been objects of search with him. No deliberate, exhaustive inquiry into all the elements of any plant or animal has ever been instituted, and till it shall be, a query may be put in every list of organismal elements over-against all the so-called chemical simple substances; although it is manifest that, in the case of the human organism, we know all the elements which are present in *large* quantity in it. At the same time, when we find an organic compound so easily detected as sugar, overlooked, till very recently, in the secretions of the liver; and so familiar a substance as ammonia, after being positively pronounced, by the most skilful and impartial chemists, to

[1] See, in reference to the three metals in question, Lehmann's *Phys. Chem.* vol. i. pp. 449, 450.

be totally absent from the blood, demonstrated, to the satisfaction of the most competent judges, to be one of its never failing and most important constituents, we must avoid dogmatizing on what substances may yet prove to be essential ingredients, even of those organisms which have for the longest time been objects of study. And as quantity is no measure of value in the case of an organismal element, we must apply a similar rule to the rarest simple substances. More than five years of research have enabled me to demonstrate the universal distribution of Fluorine throughout the mineral, vegetable, and animal kingdoms, and especially its occurrence in the higher organisms; and at length, my results have received confirmation by M. Nicklès,[1] who is about to lay his observations before the French Academy.

It thus appears, that, as regards the *kind* or *quality* of their component matter, living organisms, so far as we know them, consist chiefly of non-metallic matter; eleven out of the thirteen non-metals (including hydrogen) being found in them, whilst only six of the solidifiable metals have as yet been recognised among their components. If, however, hydrogen is a metal, as there are so many reasons for believing it to be, and if silicon is a metal, and as such better named silicium, then the list of non-metallic bodies

[1] My papers on Fluorine are contained in the Transactions of the Royal Society of Edinburgh for April 6, 1846, and April 19, 1852, and in the Proceedings of the same Society for November 1846; likewise in the reports of the British Association for 1846 and 1850, and in the Transactions of the Botanical Society of Edinburgh for 1852. I give these references in detail, because M. Nicklès is apparently unacquainted with any of my researches, and has deposited with the French Academy, a preliminary Note on *The Presence of Fluorine in the Blood*, which, ten years after I had announced the fact, he claims as a discovery which he has just made in November last.—(*Journal de Pharmacie pour Décembre* 1856. Présence du fluor dans le sang, par M. J. Nicklès. *Communiqué à l'Académie des Sciences, dans la séance du* 3 *Novembre* 1856.)

will be diminished by two, but they will still exceed the metals in number by three.[1]

So far again as *quantity* of component ingredient is concerned, the bulk and weight of all living organisms are most largely made up of non-metallic matter; charcoal and oxygen specially preponderating.

In relation, thus, both to quality and quantity of constituent elements, plants and animals are mainly aggregations of non-metals; but this forms no point of distinction between them and a multitude, perhaps the majority, of minerals;[2] nor does it warrant any conclusion as to the metals which do occur in organisms, being less important than their non-metallic elements.

Living organisms then are not chance-medleys of elements of different kinds; nor do they consist of equal quantities of all the elements; nor do they contain in greatest quantity the elements which contribute most largely to the weight of the globe.

It is true that as all plants consist chiefly of charcoal and water, the amount of vegetable matter on the globe could not be large, if carbon, hydrogen, and oxygen were not abundant; and as the great majority of animals have much lime in their skeletons, their number could not be great, if lime were a scarce substance. But it certainly is not merely because charcoal, water, and lime are plentiful that they occur in living organisms. On the other hand, both plants and animals are found to reject substances which are in abundance about them, and to appropriate others which are scantily provided by nature, and can only be very slowly

[1] The recent interesting discovery by Wöhler and Deville, that boron is crystallizable like carbon in its diamond-modification, and does not put on crystalline metallic characters, lessens the probability of silicon proving to be a metal.

[2] Certainly the majority, if silicon, which, next to oxygen, is the prevailing element in minerals, is not metallic.

accumulated even in favourable circumstances. A land plant, for example, finds in the soil which supports it much of the earth or oxide *alumina*, and very little of the alkalies potash and soda; yet it totally refuses to take any of the alumina, whilst it untiringly searches for and absorbs the alkalies; or dies if it cannot find them. A graminivorous animal finds in its food much silica, yet, with the exception of a very little in the hair, and mere traces elsewhere, silica is absent from all its structures. On the other hand, it finds in its food very little phosphate of lime but it appropriates the whole of it, expending it on the nutrition of every tissue, but especially in constructing its bones.

If we had the means of comparing the weight of an elephant's tusk, say of 150 lbs., with the tons of vegetable matter which the animal had to devour, and the hundredweights of silica which it had to reject, before it obtained a sufficient amount of phosphate of lime to form the ivory of a single tooth, we should have a startling proof that there is no necessary connexion between the quantity of raw material offered to an organism, and the quantity of that material appropriated by it.

The illustration of this truth afforded by the rejection of alumina by plants, and of silica by animals, is the more significant that it is strikingly at variance with common belief. Silica and alumina together, constitute clay, and although this occurs in no plant or animal of any kind, all plants and animals, and especially man, are held to have been created from it, and to revert to it after death. Not merely the vulgar but also the intelligent have agreed in interpreting the sacred declaration that 'the Lord God formed man of the dust of the ground,' as signifying that man was made from clay. Theologians have often undesignedly contributed to the opinion, by mixing up with this simple decla-

ration of a physical truth the purely metaphorical references of Scripture to 'the earthly house of this tabernacle' and to mankind under God's sovereignty as resembling 'Clay in the hands of the potter.' The doctrine, however, does not belong only to Christendom. In many regions of the East, Adam is held to have been a red man, and made of red clay; nay, a specimen of such loam, brought from a traditional site of the Garden of Eden near the Euphrates, was recently offered in Edinburgh for chemical analysis, to see if it could be identified as Adamic dust! Shakspere long ago counted upon a universal response when he made Hamlet too curiously consider, how

> 'Imperious Cæsar dead, and turned to clay,
> Might stop a hole to keep the wind away;'

and our latest and greatest poetess, in her *Aurora Leigh*, makes her hero *Romney* exclaim,

> 'Dear Marian, of one clay God made us all,
> And though men push and poke and paddle in't
> (As children play at fashioning dirt-pies),
> And call their fancies by the name of facts,
> Assuming difference, lordship, privilege,
> When all's plain dirt,—they come back to it at last;
> The first grave-digger proves it with a spade,
> And pats all even.' [1]

The belief is a very natural one, for no dust is more abundant than clay-dust; and plants live with their roots buried in clay, and on plants all animals, including man, feed directly or indirectly; yet the belief is without any foundation. Dust we are, and unto dust we shall return, but not into clay.

The selecting power which thus characterizes the vegetable and animal worlds each as a whole, is not less strikingly shown when we compare genera with genera, or

[1] 1st Edition, p. 139.

species with species, as to their component ingredients. In every botanic garden one may see plants requiring very different kinds of food growing side by side, and living on the same soil. Botanic gardens would be impossible but for this. If we had not only to bring the palm from South America, and the camellia from China, but also to import the very earth in which they grew, our richest gardens would exhibit a very meagre show. We stole the secret of porcelain-making from the Chinese, but it did us no good till in a few widely-separated places in Europe we discovered porcelain-clay. But the camellias, the azaleas, and tea-plants of China take as kindly to British earth as if they had never known any other; and the palms, if they sigh for brighter skies, and for breezes with warmer breaths, make no complaint against the soil or water of England. Botanic gardens are possible, because, provided their soils contain all the ingredients of plants, each will select for itself exactly what it requires.

Zoological gardens are possible for a similar reason, and illustrate the same truth. The naturally carnivorous cat may be accustomed to a vegetable diet, and the naturally graminivorous horse or ox to an animal diet, provided in both cases no ingredient essential to life is wanting, for the selecting power resident in each organism will prevent it from injuriously losing or gaining by the change.

A still more striking example of selective action is afforded by the plants and animals which simultaneously develop themselves from the same medium, such as the sea. In any rocky pool, when the tide is out, and in every thriving drawing-room aquarium, one may find the graceful plants which we call sea-weeds sipping from the mingled waters their daily fractional dose of iodine; housed sea-snails sucking from it carbonate of lime for their shells;

restless fishes extracting from it phosphate of lime to strengthen their bones; and lazy-like sponges dipping successfully into it for silica to distend the mouths of their filters.

Thus, no creature is a fortuitous concourse of atoms. Each is as definite and constant in its chemical composition as it is in its mechanical structure, or its external form. A bird does not more certainly in successive generations instinctively build its nest in the same way, than from the first moment of its embryonic life it unconsciously builds its own body out of the same materials, gathering lime to its bones, iron to its blood, and silica to its feathers.

In this way, through unnumbered centuries, each tribe of organisms has from the period of its creation followed in its structural development, a chemical formula of composition, which in the same species is constant, within narrow limits, for every one of its members, so that each plant and animal has a chemical as well as an anatomical individuality. On analysing an organism, we find certain substances, and only these, present; and we have made some progress, though as yet it is but small, in establishing the quantities in which those chemical constants occur in different species. I have called them 'constants' because the first, and, perhaps, the fullest proof that a chemical element is essential to an organism, is its invariable presence in it. A criterion like that by which Vincentius Lirinensis proposed to test Catholic religious doctrine is applicable here: *Quod semper, quod ubique, quod ab omnibus.* Whatever chemical element is found in all the individuals of a species, at all times, and in all places, is essential to each individual. This criterion requires only the qualification that neither plant nor animal can prevent non-essential substances from entering its body along with its food, and in the air and water on which it so

largely lives; so that if we analyse it whilst it is thus traversed by a non-essential element, we may mistake that for an essential ingredient. But if this unwelcome visitant be not so poisonous as to kill the subject of its intrusion, in which case analysis would be out of the question, it will soon be dismissed, for every organism has as positive a power of refusing as of choosing, and its house is its castle. It would be foolish, accordingly, to act like the census-collectors who count every one a member of the family, whom they find within its house at the moment of knocking at the door. We must, as when analysing inorganic individuals such as crystallized minerals, select various examples from different localities, and analyse each. The essential ingredients may then be readily distinguished from the incidental, as well as the extent to which one element is replaceable by another without departure from the specific chemical type. A chemical formula thus reached, will one day characterize organic species, as it now does inorganic ones.

Within the limits of variation which such analysis will show, every element discovered in a plant or animal must be regarded as essential to it. The endeavour of some to rank the ingredients found in an organism as important, in proportion as they are present in large or small quantity, is plainly fallacious. Assuredly no substances are more important to all classes of organisms than hydrogen and oxygen, which during life predominate in them; but we are not entitled to affirm that the water of which the blood chiefly consists is a more important vital constituent, than the common salt and the iron which are found in it. Blood is as invariably saline and ferruginous as it is aqueous; and it would be as unwise to disregard the iron because its amount is small, as it would be to hold the mortar in a building use-

less, because its weight is insignificant compared with that of the stones which it binds together; or to disregard the nails, because they are few, which unite the planks of a vessel; or the threads, because they are scanty, which convert a dozen furs into a single garment.

On the other hand, seeing that the more powerful any agent is, the less of it is needed to produce a given effect, very potent chemical elements cannot be expected to occur in large quantities, and hence some have proposed to consider the least abundant ingredients of an organism as those most valuable to it; so that fluorine and silicon would occupy the highest place among the elementary constituents of the animal frame. It is needless to enter into an elaborate refutation of this view. We know that one unit by weight of hydrogen is equal in *chemical* power to 200 such units of a closely analogous body, quicksilver. There is no preponderance of such power on the part of either, but only perfect equality, so that we speak of one and two hundred as the chemical *equivalents* of these bodies. Quicksilver may represent an abundant organismal element, when contrasted by equivalent with hydrogen, held to represent a scanty one, but neither chemically excels the other in such proportions; to compare the chemical powers of equal weights, is to trangress the first law of quantitative chemistry. We must in the meanwhile be content to ascertain in what proportions the elements of organisms occur in them, with no prejudice in favour of scanty or abundant occurrence as a measure of importance.

Seeing, then, that every plant and animal is an edifice like the temple of the Hebrews, built of stones squared and fashioned for their respective places before they were put together, we cannot forbear the question, why were certain building materials chosen rather than others? This choice

can have been made, no matter how brought about, only because of a peculiar fitness which they possessed beyond those equally accessible, to which they were preferred. Let us try the point in a case or two, and in the following way, limiting ourselves to the human organism.

Suppose an intelligent person, quite ignorant of both chemistry and physiology, to be taught as much of the latter science as can be learned without an acquaintance with the former, and then to have shown him the properties of all the chemical elements and their chief compounds, after which he is requested to state which of those elements is most likely to occur in the human frame.

Avoiding all minute details in reference to structural peculiarities, and not even appealing to the microscope (for it would be premature in the present state of our knowledge to attempt to explain the chemical changes which attend the development and metamorphosis of cells), the physiologist is content to teach his pupil the great general laws which regulate the changes of the human organism during life; such for example as the following:—

The living body of man unites in itself the contrasted and apparently incompatible qualities, of great stability and great mobility. It is so stable that it can last for threescore years and ten; for a hundred or more; maintaining its sharply defined individuality all the time. It is so mobile that it does not consist of entirely the same particles during any two successive moments. The dead matter of the outer world it is ever changing into its own living substance, and its living substance it is ever changing into dead matter, which, as alien to itself, it returns to the outer world. Like the heavenly bodies, it undergoes a series of secular variations, which carry it with continually-altering conditions through the several phases of embryonic, infant,

adolescent, adult, and senile life. Like certain of the heavenly bodies, also, it describes a diurnal revolution, knowing the alternations of sleep and waking, hunger and satiety, activity and rest. The reproduction of its kind involves a peculiar series of very complex changes, especially in the maternal organism. Mechanical injuries, disabling or destroying organs and tissues, require the manifestation of corresponding reparative processes. Disease, equally defacing and destructive, demands a countervailing *vis medicatrix* to neutralize its violence; or rather, disease is a battle between the organismal elements, which are quick at finding a *casus belli*, and are very rarely at perfect peace with each other. Everlasting change, and yet fixity. Unceasing struggle, and yet no schism. Civil war, and yet no anarchy. These unlike conditions are realized and harmonized every moment in our fearfully and wonderfully made bodies.

If we reduce those apparent incompatibles to their simplest expression, we shall perhaps find it in this. Physically, the human organism is an aggregation of solids and liquids, which are continually changing into each other; the solid melting into the liquid, the liquid congealing into the solid; whilst both stand so related to the air, which is the breath of life, that they are continually vaporizing into gases, and gases are continually liquefying and solidifying into them. When Hamlet exclaimed,

> 'O that this too, too solid flesh would melt,
> Thaw, and resolve itself into a dew!'

he was preferring a request which was granted before it was preferred, and which is every moment receiving fulfilment in each of us. Blood is liquefied muscle, sinew, nerve, brain, and bone. Bone, brain, nerve, sinew, and muscle are solidified blood; and at every moment flesh is becom-

ing blood, and blood flesh. The current in our veins is at once a River of the Water of Life, feeding and sustaining all that grows along its shores, and a River of the Water of Lethe, quenching in oblivion everything that it touches. Like the Nile or the other great rivers of the world, it is at the same time wearing down hills and building up continents; but with this difference, that whereas the Nile is only destructive among the mountains of Abyssinia, and only constructive in the plains of Egypt, the blood at every point in its course is simultaneously adding and abstracting. Those wondrous crimson barks or blood-cells which navigate the arteries are keen traders, and follow the rule of the African rivers, where sales are effected only by barter; but they add to this rule one peculiar to themselves, which neither civilized nor savage man cares to follow, namely, that they give away new goods in exchange for old. Here the traffickers on the Red River deposit fresh brain-particles, to replace those which the immaterial spirit has sacrificed to the expression of its thoughts; for Jeremy Taylor taught a great physical truth when he declared, long ago, that 'whilst we think a thought we die.' The eloquent preacher saw death near us at every moment, and nearer at each than at the moment before; but death is *in* us at every moment, and it is not merely *whilst*, but *because* we think a thought we die. Alas! that we cannot be content with such innocent self-slaughter, which the river of life in our veins forgives into resurrection in every case, as fast as it ripples along. It cannot help us if we overthink ourselves, and die before our time; but during life its mariners deal in all vital wares. As fast as the blacksmith wastes his muscles by each blow, they barter against the spent cordage of his arm new flesh-particles, to make it strong as before: they restore to its integrity the exhausted auditory

nerve of the musician, give the painter a new retina, and the singer a new tongue. Wherever, in a word, the million lamps of life, which keep up its flame at every point of the body, have burned to the socket, they are replaced by freshly-trimmed ones; nor is it here as with the barter of Aladdin's lamp. The new lamp is in this case the magic one; the genie has departed from the old.

Chemically, again, the human organism is the continual subject of swift changes of its composition in opposite directions. One half of the blood, which is in the arteries, is always in one chemical condition; the other half, which is in the veins, is in another condition; and the whole blood is at all times rapidly transferred through these alternations. The arterial blood is charged with oxygen; the venous with carbonic acid. These gases are partly the causes, partly the effects, partly the indices of chemical differences between the two bloods, which affect, probably, more or less all their respective ingredients. At one half-revolution of the circulation, they are changed in one way at the capillaries of the lungs, whilst oxygen is absorbed; at the other half-revolution, they are changed in another way at the capillaries of the system, whilst oxygen is lost, and carbonic acid takes its place.

There is thus continual addition of matter to the body, and continual withdrawal of matter from it; but, apart from this, and within the ring-fence of its own organism, a process of combustion, and one the very reverse, are going on together. Our bodies are at all times like the fire which was shown to the hero of the Pilgrim's Progress in Interpreter's House, which had water poured on it on one side of the wall against which it blazed, and oil on the other. Here one tissue is burning like fuel, and there another is becoming the depository of combustible matter.

We have, as it were, millions of microscopic wind-furnaces converting into carbonic acid, water-vapour, and other products of combustion, all the combustible elements of the body; and millions of blast-furnaces reducing the starch and sugar of the food, and the sulphates and phosphates of the body, into inflammable oils and other fuels, which are finally transferred to the wind-furnaces and burned there. Burning, and what we must call in contradistinction, *unburning*, thus proceed together; the flame of life, like a blow-pipe flame, exhibiting an oxidizing and a reducing action at points not far distant from each other.

There are thus, as concerns the organism, continual addition and continual abstraction; continual physical alternation of liquefaction and solidification; continual chemical alternation of combustion and reduction. The blood-vessels are at once the water-pipes of the city of Mansoul, bringing fresh springs into it, and the drain-tunnels carrying all that is waste and useless away. The heart is the one true conjuror's bottle, pouring forth, ay and at the same time, liquids the most unlike to satisfy thirsts as strange; saliva to wet the lips, tears to relieve the eye, milk to swell the mother's breast, and oil to make supple the wrestler's limbs. The whole organism is, as the old writers loved to call it, a *Microcosm*, or world in little, where in one land they are rejoicing, and in another weeping; where on this shore they are singing *Te Deum*, and on that shore *Miserere;* where at the same moment it is 'a time to love and a time to hate, a time of war and a time of peace.'

Such is the human body, ever changing, ever abiding. A temple, always complete, and yet always under repair. A mansion, which quite contents its possessor, and yet has its plan and its materials altered each moment. A machine, which never stops working, and yet is taken to pieces in

the one twinkling of an eye, and put together in the other. A cloth of gold, to which the needle is ever adding on one side of a line, and from which the scissors are ever cutting away on the other. Yes! Life, like Penelope of old, is ever weaving and unweaving the same web, whilst her grim suitors, Disease and Death, watch for her halting; only for her there is no Ulysses, who one day will in triumph return.

If the imperfect description which has been given of the human organism is in any respect faithful, it is manifest that the chemical elements which enter into its composition must exhibit the contrasted stability and mobility which so strikingly characterize itself. Suppose, then, our physiologist's pupil, guided by this rule, to study the chemist's elementary bodies, with a view to discover which of them are most suited for the living frame. Is it likely that among the sixty he would select only seventeen? that he would select the actual seventeen which are found? that he would even prefer non-metallic to metallic matter? or assign any place to abundant constituents, such as the metal of lime, or to never-failing unabundant ones, such as fluorine? He would probably select air and water, but beyond these I feel quite unable to surmise how far his Frankenstein would agree in composition with the Homo Sapiens of Linnæus. At all events, the chances are very great that he would pass over entirely that remarkable group of elements, in which two of the most characteristic ingredients of all animal organisms are included. This group contains four bodies, Phosphorus, Arsenic, Antimony, Nitrogen, with an outlying fifth one, Bismuth, which I do not at present consider; and, in the whole category of elements, no four at first sight seem more unfitted for organismal constituents than they. Phosphorus has been known for two centuries

as a dangerous combustible, and most deadly poison, which the sad and often fatal experience of the lucifer-match makers has shown to possess a peculiar antipathy to the bones, for, when it can reach them, as it can those of the jaws, it rots them away. On the poisonous properties of arsenic it is quite needless to dwell. Antimony, or Anti-Monk, betrays by its name a deadliness to man, akin to that of its name-sister, Monkshood, a still more potent killer; and for both, all men are monks. Nitrogen, on the other hand, has seemingly no properties at all; a light, thin, tasteless, insipid, insoluble, incombustible gas, to appearance good for nothing, and as such fitly symbolized in chemical tables by the letter N. Two murderers, a dangerous mediciner, and an incapable, are surely not the parties to whom any one would propose to intrust our lives! Yet the fiery phosphorus and the negative nitrogen are the two elements which, by their greater abundance in animals, and the part which they play there, most strikingly distinguish animals from plants; and they are specially important in relation to the human organism. When, moreover, we study those two elements more particularly, they singularly change characters; phosphorus, on a closer acquaintance, proving to be a very healthful and friendly occupant of the body; nitrogen prone to conceal under its look of helpless indifference the most energetic powers of making and marring, so that when occasion calls, it proves better at killing and slaying than any one of its more demonstrative brethren.

Into a more detailed consideration of these elements I will now enter, in the hope of showing, that though we might not have anticipated their presence in our bodies, we can point out many reasons why they actually are there. First of phosphorus. Its importance to the human organ-

ism is shown, *1st*, by its invariable presence in it; *2d*, by the abundance of its presence; *3d*, by the universality of its presence; *4th*, by the diversified manifestations of its presence; *5th*, by the active part which it takes in the most energetic vital processes, such as absorption, secretion, nutrition, reproduction, sensation, emotion, and all the other forms of nervous or cerebral action; *6th*, by the invariable loss of health which attends its withdrawal from the body; *7th*, by its efficacy as a restorative. A substance which is alike present in the hardest bone and the most pulpy nerve, which occurs in one form or rather series of forms in the blood, in another series in the flesh-juices, in a third in the milk, in a fourth in the brain, and probably in other modifications elsewhere in the organism, and which is associated with all its critical changes, must be pre-eminently serviceable to the body.

Phosphorus occurs in all organisms chiefly as phosphoric acid, in union with water, with mineral and organic bases, with fatty bodies, and in other forms of organic combination as yet little understood. The following exposition of the properties of the element and its chief organismal compounds may illustrate why it is so serviceable to the body.

I. Phosphorus is remarkable for the Protean shapes which it can assume. Some elementary bodies, such as gold, are familiar to us in one form, and that so beautiful that we are not curious to inquire whether the metal can assume other and less noble shapes. In truth we have but recently fully realized that a multitude of the chemical elements can masquerade in disguises, through which we with difficulty realize their individuality. Among those masqueraders a first place must be given to the element under notice.

Since about 1660, we have been familiar with phospho-

rus as a soft, semi-transparent, nearly colourless wax-like substance, possessed of a glassy structure, exhaling in the air an odour of garlic, shining even at the freezing point of water, melting a hundred degrees below the boiling point (111·5° Fahr.) of that liquid, bursting into flame in the air at a temperature a little higher, and yielding a thick white smoke condensing into a snow of phosphoric acid. This form of the element we have learned to distinguish as vitreous phosphorus. It is so inflammable, that it can be preserved with safety only under water; and there is scarcely a chemist who has not been in some degree a martyr to its flames. It is so poisonous, that not a year passes without some poor child falling a victim to the minute portion which it thoughtlessly eats from a lucifer-match, and without some uncautioned lucifer-match-maker suffering the prolonged tortures of slow poisoning, which its daily administration in infinitesimal doses infallibly occasions. It reacts so powerfully upon the air in which it is permitted to fume, that it changes its oxygen into the energetic, oxidizing, deodorizing, and bleaching agent which is known as ozone. In a word, it exhibits in an intense degree an affinity, or tendency to combine, alike with metals and non-metals, and strikingly alters each by its union with it.

In so far, then, as mobility, or susceptibility of various change is concerned, no one will question the fitness of phosphorus to become an organismal element. But till recently, we had not discovered that it can change this mobile, restless, agonistic condition for one of passive indifference and great stability.

Recent researches have shown that vitreous phosphorus is susceptible of no fewer than five modifications.

1st, It may be altered from the glassy to the crystalline condition.

2*d*, By exposure under water to air and light, it becomes a *white*, opaque, sparingly fusible body.

3*d*, By fusion and sudden cooling at a comparatively low temperature, it becomes *black* and opaque.

4*th*, By elevation to near its boiling point, and sudden cooling, it becomes viscid like sulphur in the same circumstances, and retains for a considerable period a consistence like that of caoutchouc.

5*th*, By exposure to the rays of the sun in a vacuum, or in a gas free from oxygen, or in water free from air, and excluded from air, it changes into an amorphous *red* solid.

Thus we know phosphorus as—

1. A symmetrical crystal.
2. A true vitreous body, or glass.
3. A soft elastic substance like caoutchouc.
4. A white amorphous solid.
5. A black amorphous solid.
6. A red amorphous solid.[1]

The crystalline phosphorus and the vitreous closely correspond in chemical characters, and we know little of the elastic, the white, and the black varieties; but the possibility of producing them illustrates how susceptible phosphorus is of many modifications, and in the red amorphous modification we have an indifferent form of the element, so unlike that in which we are accustomed to see phosphorus, that though it has been in the chemist's hands for more than a century, he has only very recently recognised that it is phosphorus.

It is now, however, manufactured on the large scale,[2] so

[1] See Gmelin's *Handbook of Chemistry*, Cavendish Soc. Trans., article *Phosphorus*. Prof. W. A. Miller's *Chemistry*, vol. ii. p. 593. Graham's *Chemistry*, vol. i. p. 431.

[2] Messrs. Albright, near Birmingham, have for the last five or six years pre-

that its properties may be stated and illustrated in full. It is neither crystalline nor glassy, but amorphous, and heavier than the familiar forms of phosphorus. It does not shine at the heat of freezing water, nor melt even at that of boiling water. It exhales at ordinary temperatures no vapour and no odour, nor does it become oxidized in the air, or change it into ozone. It is not poisonous even when directly administered in doses a hundred times greater than those which are fatal with vitreous phosphorus, and it may be handled with impunity. Towards other elements it shows in general a singular indifference, nor is it till we raise it to the temperature of 500° Fahr., some 470° above the heat necessary to make vitreous phosphorus begin to burn, that it starts into activity, bursting into flame, and yielding phosphoric acid. It appears to owe its peculiarities to the presence in it of much latent heat, so that it differs from vitreous phosphorus as steam does from water, and water from ice, for it is most easily produced by long maintenance of the common phosphorus at a temperature below 490°, and when heated above this point it suddenly bursts into vapour, changing with evolution of heat into the familiar modification of the element. But it can be produced by a brief exposure of the vitreous phosphorus to light, in a vacuum or non-oxygenous atmosphere, and when common phosphorus is kindled in air, it always changes in part into the red amorphous modification, which remains when the non-amorphous portion has burned away; and some interesting researches of Professor Brodie appear to prove

pared red phosphorus according to Schrötter's process, which they have patented. I am indebted to these gentlemen for the opportunity of examining large specimens of this important substance, which promises, by its comparative harmlessness, to render the manufacture, use, and carriage of lucifer matches much less dangerous than they are at present.

that the change may attend the combination of phosphorus with other bodies.

Here then is an element which can imperceptibly and quickly pass from a condition of great chemical activity to one of great chemical inertness. I suggest this susceptibility of change as one reason why phosphorus is a predominant organismal element. Without insisting on its sixfold mutability, let its twofold mobility, of which we are quite certain, be kept in view. Phosphorus, in virtue of this, may follow the blood in its changes, may oxidize in the one great set of capillaries, and be indifferent to oxygen in the other; may occur in the brain in the vitreous form, changing as quickly as the intellect or imagination demands, and literally flaming, that thoughts may breathe and words may burn; and may be present in the bones in its amorphous form, content, like an impassive caryatid, to sustain upon its unwearied shoulders the mere dead weight of stones of flesh. And what is said here of the brain, as contrasted with the bones, will apply with equal or similar force to many other organs of the body. All throughout the living system we may believe that phosphorus is found, at the centres of vital action in the active condition, and at its outlying points in the passive condition. In the one case, it is like the soldier with his loaded musket pressed to his shoulder, and his finger on the trigger, almost anticipating the command to fire; in the other, it is like the same soldier with his unloaded weapon at his side, standing at ease.

Phosphorus will react also on other bodies, according to its own condition; and as it appears that vitreous phosphorus not only oxidizes with great rapidity when it encounters air, but at the same time changes that air in part into ozone, *i.e.*, greatly exalts its oxidizing power, it will be seen that the quick oxidation of phosphorus within the organism may

often imply the simultaneous quick oxidation (through the ozone it generates) of all the surrounding oxidable substances.

It is premature to speculate on such matters, but it is desirable to notice emphatically, that physiology has not yet recognised the importance of that susceptibility of molecular change which chemists specify by the name of 'Allotropy.' It increases alike the difficulties and the resources of biology. Hitherto, we have begun with each element as if it had one narrowly-defined set of sensible characters, which we have briefly enumerated; and thereafter we have proceeded to consider its chemical compounds, with the exposition of which our zoo-chemical demonstrations have commenced. But now it appears that what we regarded as the basement floor, level with the ground, was at least one storey above it, and when we dig away the sand, we find vault covering vault, and know not as yet how many storeys lie below. Among organismal elements, not only phosphorus, but oxygen, carbon, sulphur, and chlorine are known to admit of molecular modifications. The tendency, indeed, of discovery is to show that every chemical element is in this predicament, for every day adds to the number of allotropic substances. Moreover, we can confidently affirm, that when they enter into combination, the compounds which they form often reflect the image of the modification which characterized the element at the moment of its combination, and that we may have oxides, for example, of the same composition (so far, at least, as ponderable constituents are concerned), yet very different in property.

As pre-eminent among the possessors of this variability, phosphorus is more suitable than any element we yet know, to minister to the unchanging change of the living body.

It is not, however, as elemental phosphorus, intricately

combined with organized molecules, in ways which the chemist cannot interpret in his study or imitate in his laboratory, that this organismal constant chiefly occurs. As already stated, it is present in living bodies chiefly as its highest oxide, phosphoric acid.

When a bone is burned to whiteness in the open air, it yields a crumbling chalk-like solid, significantly called bone-earth, of which the larger part is lime, whilst the remainder is in great part phosphoric acid. This acid can be separated from the bone-earth, by pouring oil of vitriol upon it, and its properties as the dominant acid of all the higher sentient organisms, are now to be considered.

Phosphoric acid has all the properties of the most powerful acids. It dissolves in water. It is intensely sour. It reddens all acidifiable vegetable blues. It perfectly saturates powerful bases. In these respects it agrees with sulphuric, nitric, hydrochloric, and acetic acids. But from all other acids possessing such properties, it differs in several singular ways, and these differences point to the cause of its organismal pre-eminence.

The first remarkable difference is its freedom from corrosiveness. The acids named above, even when considerably diluted with water, rapidly disintegrate organic bodies, and in their strongest aqueous dilutions, act like hot irons on the skin. A drop of oil of vitriol, or of the strongest aquafortis, burns the flesh like a live coal, and unless mingled with much water, excites painful and dangerous inflammation of the tissues. But the phosphoric acid extracted from bones, even when combined with a chemical minimum of water, and concentrated into a crystallizable hydrate, may be spread for a considerable time over the thinnest skin of the living body without burning, paining, or inflaming it. It is thus of all the strong acids we know, the only one

which can be set free, and that in a concentrated form, within living organisms, without causing their destruction. In this peculiarity I find one cause of its universal presence in the body; for whatever services an acid can render to an active organism, phosphoric acid can render to the full without harming it.[1]

A second peculiarity of phosphoric acid is, that, unlike the majority of equally strong acids, it does not coagulate albumen. And as this substance, familiar to all in white of egg, is largely present in the flesh, the natural juice of which contains partially-neutralized phosphoric acid,[2] and is also largely present in the brain and nerves, associated with a modification of the same acid known as oleo-phosphoric acid, we can affirm at least that the solitary potent inorganic acid compatible with the non-coagulation of albumen, is the only one found in a free (or at least partially free) state, in association with the liquid form of that important organismal constituent. These peculiarities, however, are as nothing compared with the third, which calls for special notice. The majority of acids which are soluble in water exhibit their characteristic properties most markedly when associated with the chemical minimum of water which can combine with them, and when more water is added, they show in a less degree, according to their dilution, such qualities as sourness, power to alter vegetable colours, and to saturate bases. There is thus but *one* sulphuric or nitric acid. The less water united with either, the more powerful it is, and the greater the weight of base it can neutralize. In the language of quantitative

[1] It seems worth the consideration of surgeons, whether common phosphoric acid, in virtue of its unirritating action on living tissues, and its solvent action on phosphatic calculi, may not as a *litholytic* be brought in direct contact with vesical concretions of the non-acid class, and render in some cases operations unnecessary.

[2] The tribasic, acid phosphate of potash ($2\ HO, KO + PO_5$).

chemistry, one equivalent (or chemical unit) of nitric acid can combine with one equivalent of a base, neither more nor less. This is the general rule. One unit by weight of an acid unites with one unit of base, and here the neutralizing power of the former stops, so that as dilution by water implies the spreading of the efficacious unit over a wider area, a given weight of diluted acid must neutralize a smaller weight of an undiluted base than the same weight of stronger acid will neutralize. Hence, the less amount of water, the greater the acidity of the acid; and unit of acid to unit of water is the condition of greatest strength.

But to this widely applicable rule phosphoric acid forms a remarkable exception. It is most acid when united, not with one, but with *three* units of water. In this condition, it is extracted from bones, and found (at least after death) in the blood and flesh. One unit of the acid crystallizes along with three units of water, and retains these in special combination to whatever extent it is diluted with more water. Its neutralizing power, moreover, is correspondingly threefold, so that, for example, in the bones one equivalent of it is combined with three equivalents of lime, whilst all the other bone-acids are united in single units, with a single unit of lime. An endless series of salts, similar to bone-phosphate, but containing other bases than lime, are known to chemists, who distinguish them, as a class, as the tribasic phosphates. The organismal importance, however, of this property of phosphoric acid will not appear till we look to a fourth peculiarity which it possesses.

Phosphoric acid has the singular power of dropping or casting off, as it were, one of the three units of water which it is able to retain, keeping only two, and refusing, even though dissolved in volumes of water, to take back the

third. In this modification (which is known as pyro-phosphoric acid), it has not a threefold, but only a *twofold* power of neutralizing bases, so that, for example, as it occurs in burnt bones, one equivalent is united with but two equivalents of magnesia, and an extensive series of corresponding salts is known, distinguished as the bibasic phosphates.

But further, pyro-phosphoric acid can part with one of the two units of water which it characteristically retains, as common phosphoric acid can part at once with two of its three characteristic units of water, both becoming, like the ordinary mineral acids, a compound of unit of acid to unit of water, with a onefold power of neutralizing bases. This modification has been called meta-phosphoric acid. It also forms a large series of salts, all containing one equivalent of acid to one equivalent of base, and distinguished as monobasic phosphates.

Meta-phosphoric acid, unlike the other hydrates of the acid, coagulates albumen. Dissolved in cold water, it slowly takes to itself two additional units of that body; and if boiled with the liquid, it takes them with great rapidity.

We have thus to begin with a snow-like soft solid, called anhydrous phosphoric acid, procured by burning dry phosphorus in equally dry air. When we dissolve it in water, it so unites with that liquid as to produce, according to circumstances, three acid solutions, as distinct from each other in all their properties as if they were composed of totally different ingredients. These three solutions, distinguished as common phosphoric, pyro-phosphoric, and meta-phosphoric acids (of which the first two are crystallizable as solids), are mutually convertible by loss or gain of two units or chemical equivalents of water; the first

named, which retains three such units, being the most stable, and the last, which retains but one aqueous unit, the least so.[1] The chief organismal acid is thus equal in powers to three ordinary acids, and strikingly exhibits the quality of mobility or variability, which has been shown to be so essential to the active components of living organisms. Yet triply potent as phosphoric acid is, it does not, in any of its modifications, exhibit corrosiveness or poisonousness. This has already been referred to as characterizing the tribasic acid, but is still more remarkable as characterizing the bibasic and monobasic acid, for the general rule is, that the less the amount of water in a hydrated acid, the more caustic, corrosive, and poisonous it is. But even anhydrous phosphoric acid half-deliquesced, may be kept in contact with the skin for an hour without injury, where the similar hydrate of sulphuric acid would in a few minutes reduce the tissue to charcoal.

The innocuousness, indeed, of the strongest phosphoric acid is, in many respects, as inexplicable as it is paradoxical. Chemists refer the caustic action of strong sulphuric, nitric, hydrochloric, and acetic acids, in great part, to their

[1] The three hydrates of phosphoric acid, taken in the same order as in the text, are best distinguished as tribasic, bibasic, and monobasic phosphoric acid, according to the nomenclature of Thomas Graham, Esq., Master of the Mint, our greatest authority on the subject. On the binary theory of acids and salts, each of Mr. Graham's hydrates is represented as a peculiar hydracid:—

Thus, Tribasic Acid, . . .	$PO_8 + H_3$
Bibasic Acid, . . .	$PO_7 + H_2$
Monobasic Acid, . . .	$PO_6 + H$

It is quite immaterial to the argument pursued in the text, which of the rival theories of acids be adopted. On both views, the same weight of the same three ingredients, phosphorus, oxygen, and hydrogen, is recognised as present: The only matter in dispute is, the mode in which the ingredients are arranged. Mr. Graham's view is preferred as the one more easily followed by those who have not made chemistry a special study.

intense affinity for water, which they compel the organic bodies touched by them to give up, so that their chemical integrity is destroyed. But the water which these corrosive acids take from an organized structure, anhydrous phosphoric acid can take from them. The most caustic acids known to us are, probably, sulphuric and hydrofluoric acid, but the strong hydrates of both are rendered anhydrous by phosphoric acid, which, nevertheless, does not possess a trace of their causticity. It has latterly come into extensive and most important use among scientific chemists, as a means of dehydrating or rendering waterless other substances, so remarkably does it excel them in affinity for water, and yet the powers which they owe to such an affinity are not exhibited by it. It is thus a lord paramount among acids, compelling its barons to surrender to it the prey which they have taken from the innocents, but never found robbing the innocents itself.

There is much, indeed, as yet unaccounted for in the relation of phosphoric acid to water. One should expect such a substance to dissolve in this liquid with the greatest rapidity; yet the anhydrous acid, though it hisses like hot iron when it meets water, and shows by the heat which it evolves an intense affinity for it, seems to retain that affinity only for a moment, and to have its thirst quenched by the first draught of, or rather sip of liquid, for it dissolves slowly, like snow which has barely reached the thawing temperature. Anhydrous sulphuric acid, on the other hand, not only undergoes aqueous solution with great energy and rapidity, but, long after it has acquired its unit of water, continues eagerly to combine with more, absorbing its vapour from the atmosphere, so as to desiccate everything in its neighbourhood; and the other strong acids have a similar power. Phosphoric acid is thus like a feverish

child, begging for a great bowl of water, but pushing it away the moment its lips are wetted. Sulphuric acid is like the sufferer from a gunshot wound, whose insatiable craving for water, no number of goblets can appease ; and yet the former acid can drink the latter dry.

Whatever be the explanation of this anomaly, the important fact remains, that phosphoric acid is at once more powerful than strong sulphuric acid, and less irritant than weak vinegar, so that it can innocently traverse every part of the body. But of what service, it may be asked, is it to the body to be traversed by an acid whether innocuous or irritant ? To this, in the meanwhile, it will be sufficient to reply, that the chief chemical compounds in the organism either are or contain salts, which are produced by the union of acids with bases. A great part, therefore, of organismal chemistry is the chemistry of acids ; and we are now to look at the way in which phosphoric acid, when it ceases to be free and unites with bases, serves the organism by the kind of salts which it forms. Common or tribasic phosphoric acid, *i.e.*, 1 unit of anhydrous phosphoric acid combined with 3 units of water, can exchange these in whole or in part for units of base.[1] It may exchange the water entirely for one base, as it does when it forms the bone-phosphate of lime, which consists of 3 units of lime to 1 of anhydrous phosphoric acid ; or it may give away only 2 units of water, receiving in return the same number of units of base, as in the phosphate of soda of the blood, which consists of 2 units of soda and 1 unit of water, added to the constant unit of anhydrous acid ; or it may give away only

[1] Strictly speaking, the water is acting as base, so that the exchange is of units of aqueous base for units of some other base, but as it might confuse the general reader to call water a base, I have avoided this mode of expression although it is the customary one among chemists.

1 unit of water and receive in return 1 unit of base, as in the phosphate of potash of the flesh, which consists of 2 units of water and 1 of potash to 1 of acid. Moreover, where 1 unit of water is retained, each of the 2 given away may be exchanged for a separate base as in microcosmic salt, where 1 unit of soda, 1 unit of ammonia (oxide of ammonium), and 1 unit of water, are together combined with 1 unit of acid. The same acid thus forms, by variations of base, soluble, insoluble, acid, alkaline, and neutral salts. Further: whereas with the same base, ordinary acids form but one salt or compound, tribasic phosphoric acid can form three. Thus, whether we add caustic soda or carbonate of soda, or muriate of soda (chloride of sodium), to sulphuric acid, we obtain the same Glauber's salt or sulphate of soda containing 1 unit of acid to 1 unit of base. But if we evaporate together tribasic phosphoric acid and caustic soda, we obtain a salt with 3 units of soda to 1 of anhydrous acid: if we pour on carbonate of soda the tribasic liquid, we obtain a salt containing 2 units of soda (and 1 of water) to 1 of anhydrous acid; and if we substitute muriate for carbonate of soda, we obtain a salt containing 1 unit of soda (and 2 of water) to 1 of anhydrous acid. Muriate and carbonate of soda are both largely present in the body, and phosphoric acid must continually encounter them, but it will form a different salt with each, where sulphuric and all ordinary acids would form the same salt with both.

Once more: when tribasic phosphoric acid by parting with 1 unit of water becomes bibasic, it may form salts with 1 unit of water and 1 of base; or with two units of the same base; or with 2 units each of a different base; and when the tribasic acid parts with 2 units of water and becomes monobasic, it can act the part of an ordinary acid. Moreover, without loss or gain, but only by a new arrange-

ment of particles, a hydrated phosphate of one class may change into a phosphate of another.

Even this lengthened statement does not exhaust the modifications of phosphoric acid ; two additional classes of salts have been described,[1] and phosphates of different classes can unite *as salts* with each other. The number accordingly of possible phosphates is beyond calculation, and the quality of variability appears at its maximum in the compounds of phosphoric acid.

Limiting our attention to the well-known modifications of phosphoric acid, we may sketch in outline how they may render service to the body. The sketch can be only a fancy-picture, yet it may be one mirroring and shadowing, however faintly, the reality of nature.

A child is beginning to walk, and the bones of its limbs must be strengthened and hardened. Phosphoric acid accordingly carries with it 3 units of lime to them, and renders them solid and firm. But the bones of its skull must remain comparatively soft and yielding, for it has many a fall, and the more elastic these bones are, the less will it suffer when its head strikes a hard object, so that in them we may suppose the phosphoric acid to retain but 2 units of lime and to form a softer, less consistent solid. And the cartilages of the ribs must be still more supple and elastic, so that in them the phosphoric acid may be supposed to be combined with but one unit of base, as the uncrystalline gelatinous metaphosphate.[2] On the other hand, its teeth must be

[1] Fleitmann and Henneberg's phosphates, intermediate between the monobasic and bibasic classes, and Maddrell's peculiar double metaphosphates, are described and commented on by Mr. Graham in his *Elements of Chemistry*, vol. i. 2d edit. pp. 448, 449.

[2] 'Von Bibra has made the beautiful observation that those bones which are the most exposed to mechanical influences contain the largest quantity of earthy

harder than its hardest bones, and a new demand is made on lime-phosphates to associate themselves with other lime salts (especially fluoride of calcium) to form the cutting edges and grinding faces of the incisors and molars. All the while also, the blood must be kept alkaline, that oxidation of the tissues may be promoted, and albumen retained in solution; and yet it must not be too alkaline, or tissues and albumen will both be destroyed, and the carbonic acid developed at the systemic capillaries will not be exchanged for oxygen, when the blood is exposed to that gas at the lungs. So, phosphoric acid provides a salt containing 2 units of soda and 1 of water which is sufficiently alkaline to promote oxidation, dissolve albumen, and absorb carbonic acid, and yet holds the latter so loosely, that it instantly exchanges it for oxygen, when it encounters that gas in the pulmonary capillaries. Again: the flesh-juice must be kept acid (perhaps as has been suggested, in electro-polar opposition to the alkalinity of the blood, as affecting the transmission of the electrical currents which are now known to traverse the tissues), and phosphoric acid provides a salt, containing 2 units of water and 1 of potash, which secures the requisite

constituents (chiefly phosphate of lime.) The action of this law is manifested even in different families of the same class of animals; thus, for instance, in the Rasores or scraping birds, the femur contains the largest quantity of phosphate of lime, in the Grallatores or waders, the tibia, and in all other birds the humerus.'—Lehmann's *Physiological Chemistry*, Cav. Soc. Trans., vol. i. p. 414.

The phosphate of lime in bones was represented by Berzelius as 8 Ca O, 3 PO_5; but according to Heintz and Rose it has the composition given previously in the text, 3 Ca, O, PO_5. In reality, however, neither of these formulæ will always apply to bones, although the latter probably represents the condition of the greater part of their lime phosphate. From my own results, and those of others in the course of agricultural analyses of bone earth, I cannot avoid inferring that several phosphates of lime exist in bones, although in the ash of the latter the nature of these salts as they occurred in the living organism cannot be ascertained. I have felt at liberty accordingly to assume as possible the phosphates, referred to in the text as existing in the child's skull and ribs.

acidity. Further : in some of the serous and other liquids of the body, a changeable salt is required ; and for this phosphoric acid provides, by combining with soda, ammonia, and water, to produce microcosmic salt which is alkaline in its integrity, but by parting with the easily lost, volatile ammonia, becomes acid.[1]

All those compounds are needed in the adult as well as in the infant organism. With the adult we may further connect such an incident as the fracture of a bone, which is repaired by a beautiful process of splicing, during which phosphates, first very soluble, then moderately so, then slightly so, are finally succeeded by dense insoluble bone-earth, filling up the breach till it becomes the strongest part of the reunited bone. And as counterpart of this, we have the most solid bone dissolving under the pressure of a throbbing (aneurismal) blood-vessel, which unless the bone gave way would first torture, and then kill the whole body. Particle by particle, the petrified ivory is pressed, softened, melted, dissolved, and washed away by the same potent acid which hardened it from a thin liquid into a compact solid.

At all periods, moreover, in the life of the body, the liquid albumen and fibrin of the blood are becoming solid albumen and fibrin in the tissues. Both are also becoming, in the nursing mother, the casein of her milk, and that casein in her suckling's body is becoming the albumen and fibrin of its flesh and blood, and building up its organs in other ways.

Each of these blood-forming, flesh-forming, milk-forming, tissue-forming bodies, albumen, fibrin, and casein, and likewise their analogue gelatine, are inseparably accompanied in all their liquefactions, solidifications, and transmutations

[1] Lehmann's *Physiol. Chem.* Cav. Soc. Trans., vol. i. p. 369.

by phosphates, which, in virtue of their mobility, are able to liquefy, solidify, and undergo transmutation as the body which they accompany does. We cannot pretend to follow those changes step by step, for they occur within the inaccessible penetralia of a living structure ; but certain it is that the phosphates accommodate themselves to changes which no other salts we know could submit to.

In the particular cases given above, there may be great misapprehension and even signal error. But in the general estimate of the organismal suitableness of phosphates beyond all other salts, there cannot be much mistake. Chemical unions have been compared to marriages, and chemical compounds to wedded pairs. If the comparison be accepted, then the great majority of the mineral acids are monogamists and wedded each to a single base ; but phosphoric acid, like an Eastern patriarch, has the privilege if he pleases of wedding three bases, although he is often satisfied with two, and can cheerfully content himself with one. Or, to vary the figure more expressively, the ordinary acids are like the Hindoos under the domination of caste, and when hired as servants stipulate to carry but one thing, and the minimum weight of that. Phosphoric acid is an English servant of all work, lifting three loads at a time, of any three things that require to be lifted, and willing at all times to make himself generally useful.

Putting all figure aside, we may affirm that no acid is known to us, approaching to phosphoric acid in susceptibility of various modification. Even if we were to suppose, that as a hermit crab tries shell after shell till he finds one to fit him, the living organism had made trial in turn of all the mineral acids, we cannot imagine it finally selecting any one but phosphoric acid.

For a knowledge of its remarkable properties we are

chiefly indebted to Professor Graham, who was the first also to suggest that its manifold variability specially qualified it for being what I may term the organismal acid *par excellence.* 'Phosphoric acid,' he observes, 'is one of the links by which mineral and organic compounds are connected. And it may be reasonably supposed that it is that pliancy of constitution which peculiarly adapts the phosphoric above all other mineral acids to the wants of the animal economy.'[1] He also illustrates this remarkable 'pliancy' by the conversion which the hydrated metaphosphate of soda (Na O, $PO_5 + HO$) undergoes at 300° Fahr. into the pyro-phosphate of soda and water (Na O, HO, + PO_5), remarking that its conversion 'exhibits a change of nature, without a change of composition, such as often occurs in organic compounds, but rarely admits of so satisfactory an explanation.'[2]

I would add that the occurrence in plants of *organic* acids which are polybasic, such as tartaric, citric, meconic, and even, as it would seem, oxalic acid, points to the organismal importance of polybasic acids throughout the living kingdom, and suggests the probability of organic acids of the same character occurring in animals, which our present methods of analysis do not enable us to reach. The acids of plants have not the pliancy of phosphoric acid, but seem generally as tartaric acid (which is *only* bibasic, like pyrophosphoric acid) to be permanently non-monobasic *in one degree*, but this lesser pliancy is in accordance with the

[1] *Elements of Chemistry*, 2d edition, vol. i. p. 451.

[2] *Op. cit.* p. 447. Lehmann has fully appreciated these conclusions, although he hesitates to adopt them, observing that 'it is almost self-evident that no salts of any other acid could be so usefully applied in the metamorphosis of tissue, as those of phosphoric acid, etc.'—(*Physiological Chemistry*, Cav. Soc. Trans., vol. i. p. 440). His work appeared in English in 1851, when I first became acquainted with it. The statements in the text regarding phosphoric acid, I have in greater part taught publicly in Edinburgh since 1840.

simpler chemical changes of vegetable organisms, nor is the power of their organic acids small. Tartaric acid is much more potent than pyro-phosphoric acid, and can transfer at once two such powerful and related bases as potash and soda, in the form of Rochelle salt, into plants. Its whole series of two-based salts is a remarkable one. Oxalic acid forms a not less varied class of so-called super-salts ; and those of citric acid are many and singular also. It would seem that a monobasic acid is too narrowly endowed and one-sided to suit the constantly varying exigencies of a plant.

Among the lower animals, as phosphoric acid disappears from their skeletons, carbonic acid takes its place, but, as we see in the shells of molluscous animals, consisting largely of carbonate of lime, with the production of a substance admitting of no such varied interstitial changes, as occur in phosphatic skeletons. Yet carbonic acid is a much more pliant acid than many, and has good, if not indisputable claims to be counted bibasic : at all events it forms many double salts.[1]

And even in the lowest animals, where silica replaces alike phosphate and carbonate of lime, serving alone to constitute their skeletons and hard appendages, we encounter a substance which is innocuous, soluble in water, forming very peculiar hydrates, and susceptible of a gelatinous, an amorphous, and a crystalline modification. It has thus the conjoined mobility and stability which seem so essential to organismal ingredients. Further, it has an almost unique power of uniting at the same time with many bases, as we

[1] Similar claims are advanced for sulphuric acid and cannot be disallowed ; but it certainly is far less feebly bibasic than tartaric or pyro-phosphoric acid, even though a sulphate of soda and potash can be formed ; and the acid bisulphate of potash is as incompatible with animal organisms as slightly diluted oil of vitriol.

see in the silicates of the mineral kingdom, in glass and in porcelain; and this property may be turned to account in furnishing sponges and others of the lower organisms with the bases which contribute to their growth;[1] as these bases conversely may be the media through which silica enters the organism.

Such are some of the reasons which may be given in explanation of the presence of phosphorus, and especially of phosphoric acid, in the bodies of the higher animals, and in that of man. The subject has been considered purely from a chemist's point of view, without reference to any particular theory of life, or hypothesis regarding the existence or sphere of a special vital force. For nothing is further from my intention than to imply that such a knowledge of the properties of the chemical elements as we can acquire in a laboratory, is sufficient to explain their function as organismal ingredients. It is but one of the data essential to the solution of a most difficult problem; but it is a most important datum, and to the extent that the phenomena referred to in the preceding pages are unquestionable physical truths, they must receive full recognition in every coherent theory of life.

It remains to discuss, from the same point of view, but much more briefly, nitrogen and iron as organismal elements.

Nitrogen, or as it is otherwise called azote, which stands at the greatest distance from phosphorus in the group which includes both, is like its analogue, at once very fixed and

[1] Since reaching this conclusion, I find that Mr. Graham without reference to organic structures has suggested 'that silicic, like phosphoric acid, forms several classes of salts.'—(*Elements of Chemistry*, second edition, vol. i. p. 395.) This view was not contemplated in the text, but would as well as that proposed, provide for the transmission of bases and silica to silicious organisms.

very variable in properties, but in a way peculiar to itself. Its free or uncombined state is its stable condition. So far as we know, it has no allotropic modifications. In the one shape, that of a permanent elastic fluid, in which it presents itself, it is astonishingly inert. Without taste, odour, or colour, incombustible at ordinary temperatures, and not supporting combustion, very slightly soluble in all liquids, free from acidity and alkalinity, and not poisonous, it occupies the same neutral or negative place among gases that water does among liquids. It unites directly with no other element at common temperatures, and with but one or two at higher ones. This indifference to direct combination is closely associated with its great elasticity as a gas. It is probably, indeed, the body which presents the best example of gasëity or gaseous elasticity. The only bodies which can compare with it in this respect are oxygen and hydrogen, which, like it, have never been liquefied. But oxygen is much more soluble than nitrogen in water and other liquids, and directly unites with many bodies, so as to form solid as well as liquid compounds, from which it is with difficulty set free, and re-converted into an elastic fluid.

It does not appear that hydrogen is more soluble in liquids than nitrogen ; but it unites directly with many bodies, and forms both liquid and solid compounds which are stable and enduring, so that it is mediately much more liquefiable and solidifiable than nitrogen.

This pre-eminent elasticity as a gas peculiarly qualifies it to serve the animal organism in its performance of the great function of respiration. Indifferent to all other elements, it dilutes oxygen to a point compatible with its effecting the needful slow combustion of the body, which, if undiluted, it would rapidly burn away. Gaseous nitrogen thus goes the round of the circulation, taking no part in the

changes to which the blood ministers, and after making the 'grand tour' as a seemingly unobservant traveller, returns to the lungs and the atmosphere exactly as it left them.[1]

But though free nitrogen will scarcely unite with a single other free element, by indirect processes it can be made to unite with nearly all the elements; and the compounds which it forms are among the most remarkable which the chemist knows; acids the most potent, such as nitric acid; alkalies the most powerful, of which ammonia is one among a multitude; dyes the most useful, such as indigo; medicines the most energetic, such as quinine; poisons the most deadly, such as prussic acid and strychnia; besides endless other substances, belonging to every category of chemical compounds.

To the nitrogenous bodies as a class, belongs as a distinctive property the utmost readiness to undergo change, and exactly because they contain an element indifferent to change. Its great gaseous elasticity prevents it from entering into combination, and its great tendency to recover the gaseous form causes it readily to abandon its compounds. As Gmelin expresses it, 'Nitrogen has probably the greatest affinity of all ponderable bodies for heat, with which it constantly tends to form a gas. Consequently, many of its compounds are decomposed by slight causes, with extreme

[1] Nitrogen is not of less service to organisms as the chief constituent in weight and bulk of the atmosphere, inasmuch as it diminishes the rapidity of combustion and oxidation at the earth's surface; whilst as a great gaseous envelope which the ocean and tributary waters cannot dissolve, and which neither acts injuriously on rocks, plants, or animals, nor is altered in quality by them, it forms a permanent medium for the production of winds, and a moderator and equalizer of the sidereal light, heat, and other agencies determining climatic differences, such as no other gas, simple or compound, known to us could be. But however important such services are to the entire vegetable and animal world, they are rendered outside of the organism, and cannot be added to the list of good qualities which belong to nitrogen as an organismal element.

suddenness, the nitrogen being disengaged in the gaseous form, and often producing the most violent explosions.'[1]

One mode in which the characteristic longing of nitrogen for freedom displays itself, is, as Gmelin implies, by conferring explosiveness on its compounds. I need only name gunpowder; the various bodies of which gun-cotton is the type; percussion-cap powder, and the other fulminates; the so-called ammoniuret of gold; and the chloride and iodide of nitrogen.

In a greatly lessened degree, this chemical fragility and instability are conferred by nitrogen upon the compounds which it forms within living organisms. The immensely greater and more numerous chemical changes which characterize animals than plants, are essentially connected with the much greater abundance of nitrogen in the former. The difference between the slightly alterable, slowly combustible vegetable cotton, a compound of carbon, hydrogen, and oxygen, and the spontaneously decomposable, explosive gun-cotton, which differs from it in quality of ingredients by the addition of nitrogen, is typical of the distinction between the enduring non-nitrogenous vegetable compounds, and the spontaneously changeable nitrogenous animal compounds; although in this particular case the increase of oxygen in the gun-cotton exaggerates the instability to the point of explosiveness.

The fibrin, albumen, casein, and gelatine which form the largest part of the muscles, the brain, the nerves, and the soft portion of the bones, as well as of the non-aqueous part of blood, milk, and the other animal fluids, contain much nitrogen, and in the revolution of the circulation, this gas is unceasingly availing itself of its power to become free, to change those bodies in a multitude of ways. At

[1] *Handbook of Chemistry*, Cav. Soc. Trans., vol. ii. p. 373.

all the glands, nitrogenous compounds are present, taking active part in those mysterious processes by which the blood is filtered, transmuted, re-created, and vitalized into bodies unlike itself. During the germination of seeds, we can trace the beginning of the process, as a cycle of chemical changes, to the action of oxygen on nitrogenous substances, which begin at once to change, and soon involve all the non-nitrogenous compounds in change also. During the fermentation and putrefaction of vegetable and animal substances, we find in like manner the alteration beginning with a nitrogenous compound, which, though present in minute quantity, commences an intestine disturbance destined to proceed till everything is altered. Leaven is one of the nitrogenous bodies, and it is sacredly proverbial that a little leaven leavens the whole lump. The curdling of milk by rennet is a similar phenomenon; so also is digestion in its first stage (which we can imitate artificially), as it occurs in the stomach. The morbific matters which develop diseases such as small-pox, are, so far as our limited knowledge goes, nitrogenous compounds, and we have reason to believe that their action in propagating disease resembles that of the azotized body diastase (a modification of albumen) in the germination of seeds, and of the albuminous yeast in fermenting sugar. The healthy phenomena of secretion seem to be, in many respects, similar in character; a readily changeable nitrogenous compound in the process of change, fermenting, as it were, the blood into milk, tears, saliva, or the like.

It is not to be denied that we are quite unable to explain why the fact of a nitrogenous body, undergoing decomposition in the neighbourhood of another, and it may be non-nitrogenous body, should cause that other to decompose, although it gives nothing to it, and takes nothing from it:

why, for example, sugar, a compound of carbon, hydrogen, and oxygen, should change into alcohol and carbonic acid, because vegetable albumen or yeast is changing side by side with it into substances totally different. But we know that the sugar, if alone, would *not* change, and that the albumen, though alone, *would* change, and that when both are placed together the change always *begins* with the albumen. Hence whatever obscurities remain, we are certain of the great changeableness of the nitrogen compounds, and of their power to involve other compounds in great changes also. It is thus that the mobility of nitrogen makes it pre-eminently the modifier of the living organism. Like a half-reclaimed gipsy from the wilds, it is ever seeking to be free again, and, not content with its own freedom, is ever tempting others not of gipsy blood to escape from thraldom. Like a bird of strong beak and broad wing, whose proper place is the sky, it opens the door of its aviary, and rouses and flutters the other and more peaceful birds, till they fly with it, although they soon part company.

Of all the elements, it is at first the least attractive to the chemist; but in the end no one rivets his attention more. His early indifference to it is a tribute to its stability; his lasting esteem for it is a tribute to its mobility. Its twofold character is the measure of its organismal importance.

The elements hitherto considered are all non-metallic, but this sketch would be blameably imperfect if no organismal metal were referred to. And among the organismal metals, iron is *par excellence* the metal, as certainly as it is, by the testimony of ages, industrially the most excellent of them all. All countries have honoured the smith, and he would wonder more than he does at his own skill, if he realized that the iron which he hammers is hammered not

merely by iron in his hand, but also by iron in his blood. Yet the function of this iron is so little known, that, though statistical men have calculated how many railroads might be made out of the blood-iron of a generation of mankind, the most acute and accomplished chemists tell us, to take the words of one, that 'we are unfortunately perfectly ignorant regarding the special uses of iron in the animal economy.'[1] And I have to turn to a poet to find a reason why it is so useful. Alfred Tennyson, in his Princess, makes the father of his heroine exclaim, when his stately daughter shows no signs of relenting towards the wounded prince,—

> 'I've heard that there is iron in the blood,
> And I believe it.'

Old King Gama's final cause for iron in the blood was to secure 'a steel temper' for those in whose veins it ran largely. He would have promised the chemist a large percentage of ferric oxide from the blood of the Great Captain, whom his countrymen loved to call the Iron Duke. This is the only final cause I remember to have seen assigned for blood being chalybeate. Perhaps the fine satire of the poet may quicken us to discover others.

Iron is intermediate in properties between the very oxidable metals, such as potassium, and the very unoxidable metals, such as gold. The former yield compounds too fixed, the latter compounds too variable, for the necessities of the living organism with its nicely-balanced affinities, and its stable-unstable equilibrium. Far from either extreme, iron belongs to a group including aluminium, chromium, manganese, nickel, and cobalt; but it differs from them all, and conjoins fixity and variability to an extent which none of them do.

[1] Lehmann's *Physiological Chemistry*, Cav. Soc. Trans., vol. i. p. 443.

Iron as a metal is readily crystallizable; oxidable at ordinary temperatures, even in mass; peculiarly susceptible of magnetization; fusible only at a very high temperature; agglutinating, so as to admit of welding occurring at a somewhat lower heat; and possessed at the same, and at higher temperatures, of a peculiar affinity for carbon. It is further remarkable as admitting of a singular passive, as well as an active electrical condition. Iron forms three important compounds with oxygen, besides a fourth (ferric acid), not requiring notice. The first, or protoxide, which consists of 1 unit of metal to 1 of oxygen, is a powerful base. The third, or peroxide, which consists of 1 unit of metal to $1\frac{1}{2}$ of oxygen, is a weak base, and cannot unite with carbonic acid. The second, which, as compared with the first and third, is intermediate in composition, and also in properties, especially so far as basic power is concerned, is strikingly characterized by being magnetic, and is called in consequence the magnetic oxide. Through these three stages of oxidation, iron can rapidly pass backwards and forwards, altering its basic and magnetic powers as it changes. As peroxide, it has a remarkable attraction for organic matter, familiarly exemplified by the difficulty experienced in removing iron-stains from linen, and turned to excellent account by the dyer and calico-printer. This property does not belong to the protoxide, but all the oxides of iron resist precipitation from their salts by alkalies when organic substances like sugar are present, in consequence, apparently, of combining with them.

With the great majority of the non-metallic elements, iron forms compounds similar to those which it forms with oxygen. Among these are the remarkable combinations with carbon, which confer upon cast-iron and steel their valuable properties, and the curiously complex radicals with

carbon and nitrogen (ferrocyanogen and ferridcyanogen), which occur, for example, in prussian blue, where iron in part acts as a metal, in part acts as a non-metal, as if it replaced both the sodium and the chlorine of common salt.

In virtue of those properties, iron can accommodate itself as few metals can, to the metamorphoses of the organism. In the arterial blood full of oxygen, it can become a peroxide, cleaving like a dyer's mordant to the organic matter of the corpuscles or blood-cells. In the venous blood, containing little oxygen, it can become protoxide, perhaps combining, as has been suggested, with carbonic acid. At both sets of capillaries, it may, at the crisis of change of the blood from venous to arterial, and from arterial to venous, transiently become the intermediate magnetic oxide. In one or other of those forms, or in similarly variable states of combination with other elements than oxygen, it can enter into the composition of the various solids and fluids of the body in which it is found occurring, and perform, as it does even in the inorganic ferrocyanides, exactly opposite functions in neighbouring portions of the same tissue. At the same time, its combinations are far removed from the category of fragile chemical compounds; even those with organic substances, such as the dye-mordants, resisting the decomposing action of powerful acids and alkalies.

Now, let the characters of iron which have been noted be regarded simply as exponents of a conjoined mobility and stability, without attaching any value to the particular modes in which those characters are supposed above to be organismally serviceable, and let us see how far the metals most resembling iron agree with it in such properties as the dominant metal of the body must possess. Chromium has a basic peroxide, and a strongly acid, extremely unstable, higher oxide (chromic acid), but no protoxide or interme-

diate oxide. Practically it could occur in the body only as the basic oxide, a substance having few affinities, for chromic acid is rapidly destroyed by organic substances, and reacts destructively on them, so that it is not surprising that its salts are poisonous.

Aluminium forms only a peroxide, alumina, so that it is an unpliant, unaccommodating metal. Alumina, moreover (the dyer's most useful mordant), has so excessive an attraction for organic matter, with which it forms insoluble compounds, that it cannot take an active part in organismal changes. In truth, when taken internally, it is prevented by this precipitation in an insoluble form along with the first organic substance which it encounters, from entering the blood except in minute quantity, and it is not retained there.[1] If, indeed, there is any justice in the statement that bakers are in the habitual practice of adding alum to bread, we must be continually swallowing alumina, yet none is found in our blood.

Manganese as a metal is the very reverse of aluminium, and too variable for the wants of the living economy. It resembles iron, but has a wider range of affinities, and it is very feebly magnetic. It oxidizes so rapidly in air, that it can only be preserved in sealed tubes, or under liquids containing no oxygen. In accordance with this oxidability, it forms four non-acid oxides, three corresponding to those of iron, but the fourth, or black oxide, having no analogue among the iron-compounds; and two acid oxides, one manganic acid, corresponding to ferric acid, and like it very unstable, the other permanganic acid, also, though in a less degree, an unstable compound. This susceptibility of oxidation in various degrees, which, moreover, implies a power of uniting variously with other bodies than oxygen, appears

[1] Lehmann's *Physiological Chemistry*, Cav. Soc. Trans., vol. i. p. 449.

to unfit manganese for taking a prominent part as an organismal metal. It does occur in minute quantity in the animal body along with iron, as if to supplement it, but it is more abundant in the spent tissues than in any of the fluids that take part in the vital functions.[1] It appears indeed to be hurried out of the system in virtue of the great mobility of its compounds.

The two metals which most resemble iron are cobalt and nickel. They produce oxides similar to those of iron, and are strongly magnetic. Their affinity for oxygen, however, is less than that of iron, for they remain untarnished where iron rusts. They also dissolve more slowly than it in dilute acids. Their higher oxides are not basic. Their peroxides have not the stability of the peroxide of iron, nor, so far as appears, do they possess the attraction for organic matter which belongs to that body ; neither do they form a sharply defined intermediate oxide, like the magnetic oxide of iron. They would not then, if substituted for iron in the living organism, equal it in power, nor do their properties appear to suit the wants of the body better, or indeed so well as those of iron do. Yet they resemble iron so much, that we can well suppose conditions of the system, in which they might be serviceable, and my colleague in the University, Professor Simpson, has long been in the practice of administering salts of nickel in those diseases which are accompanied by a deficiency of red globules in the blood. In such cases iron is generally administered, and often with marked utility, but sometimes it is of no service, and then nickel is often beneficial. Dr. Simpson called my attention to this fact more than two years ago, simply as an experiential result, and not as reached through any such theory as that followed above. The fact is on this account the more in-

[1] *Op. cit.* p. 448.

teresting to me, and my colleague's anticipation that the blood, if rigidly analysed, will always be found to contain nickel, may be confirmed ; although, on the other hand, it is quite possible that there may be abnormal conditions of the system, where a metal of the iron group may be more useful than iron itself, not to the extent of its similarity, but of its dissimilarity to that metal ; as manganese for example, where the metamorphosis of tissues is too slow ; aluminium where it is too swift. It may be thus that nickel, as well as cobalt, proves serviceable as a tonic ; and in that case we should not expect to find them among the normal ingredients of the blood.

Iron, then, is a unique metal. We could replace it by no other without a sacrifice of properties which are serviceable to the higher organisms. More than this it might be unreasonable to affirm. But there is one feature of its uniqueness which is worth a moment's further consideration. Except nickel and cobalt, it is the only decidedly magnetic metal, and it is more magnetic than they. It must influence the body in virtue of its magnetism in a way no non-magnetic metal could, and its magnetic condition must be continually altering. The patients of Reichenbach may sometimes have deceived themselves, or him, or both, when they declared that their sensations were different, according as they lay along or across the magnetic meridian ; but it is certain that the iron in our bodies must be in a different magnetic condition in the opposite positions, and it is reasonable to suppose that some persons may be sensitive enough to appreciate the difference. At all events, the observations of Faraday on the magnetic condition of flesh and of living animals, demonstrate that the organismal iron is magnetically active. We know also that magnetism cannot be developed without a simultaneous

development of electricity, so that magnetic changes in the ferruginous blood and flesh must be accompanied by electrical changes. Electricity also invariably develops magnetism, and we know that electrical currents are constantly traversing the muscles and other organs. Such currents will react on the magnetic masses in their neighbourhood and be reacted on by them, with a corresponding exaltation of the intensity alike of the electricity and the magnetism.

Further, the peculiar force or polarity which acts along the nerves resembles in many respects electrical and magnetic force. It is probable that all three forces or polarities powerfully influence each other, and that the magnetizable iron of the body is continually taking part in such reciprocal actions. If, moreover, the iron in the blood-vessels, as has been suggested previously, becomes magnetic oxide at each half-revolution of the blood, it will be much more magnetic at each of the great crises of the circulation than at any other period. I feel at least assured that the magnetic qualities of iron are among its organismal virtues, and that copper, for example, however suitable otherwise, could never perfectly replace iron, inasmuch as it is devoid of all but traces of magnetic power.

Such is an endeavour, most imperfect and inadequate, to exemplify one mode in which we may hope to discover why living creatures consist of certain chemical substances rather than of others. I ask for an indulgent estimate of a method of research in which I have scarcely a predecessor; but I submit to criticism examples of the method, because I believe it to be logically free from objection. It only assumes that whatever properties a chemical element possesses before its entrance into an organism, it retains after its entrance. Thus, if iron be crystallizable, magnetizable, electrifiable, oxidable in various degrees, and ready to unite

with organic matters of the body, I assume that it will continue to exhibit those properties within it, whatever may be the additional properties which it manifests in virtue of its being placed in such new conditions as can be realized only in a living organism. When we examine substances in a perfectly dark apartment we discern no colour in them, but when we carry them with us into a lighted room, and perceive the tints which they then display, we do not doubt that they retain all the properties which they exhibited in darkness; and that these moreover are closely connected with their assumption of colour when light falls upon them. We make a similar but not less legitimate assumption, when we take for granted that all the properties which exist in an element when part of a dead mass, remain in it when part of a living one. Such a mode of inquiry, accordingly, as I have suggested, may be prosecuted equally well under the guidance of almost any hypothesis, or theory of life, or without hypothesis or theory at all. And it cannot fail to yield important results.

The careful study of each of the chemical elements with a view to ascertain why it is suitable or unsuitable to become a component of a living organism, may often enable us to anticipate physiological discoveries; as, conversely, the careful study of the molecular changes which occur in living organisms, may enable us to anticipate chemical discoveries in reference to inorganic bodies.

It has always seemed to me very remarkable that the sciences which are mutually dependent, should so rarely be found furnishing each other with principles which can be used *deductively* as organons of discovery. The chemist, for example, might have said to the physiologist, I find, from my experiments on phosphoric acid and its salts, that it is so unique in its conjoined mobility, stability, and manifold

mutability, that I predict you will find it largely present in organisms, and taking an active part in their most characteristic metamorphoses. Or the physiologist might have said to the chemist, I find this phosphoric acid so universally present in the organs of the living body, assisting in functions so different, and accommodating itself to changes of condition so great, that I am certain if you examine its inorganic compounds, you will find them unlike those of any other acid, much more numerous, and very dissimilar to each other.

To take another example. The fact of but one set of tubes being provided in our bodies to convey air *to* the lungs and *from* the lungs, and the fact that gases, irrespective of chemical affinity and of difference in relative density, rapidly intermingle and exchange places, stand in direct connexion with each other. The natural philosopher might have said to the physiologist, I find that a peculiar diffusive force comes into play when unlike gases meet each other, so that, in a way liquids cannot do, they exchange places with great rapidity, and pass in opposite directions along the narrowest tube. I predict, accordingly, that though one set of vessels may be provided to carry blood to the lungs, and another to carry blood from them, a single set of tubes will be found all that is provided to carry air to and from those organs, and one channel will prove to be sufficient for inspiration and expiration. Or the physiologist might have said to the physicist, I find living organisms inspiring and expiring through a single canal, which, moreover, in many of them is a tube with rigid walls: there must, therefore, be an unsuspected power of intermingling, and exchanging places on the part of gases, which, if you seek for, you will certainly find. The physiological and the physical fact, however, were discovered independently.

Occasionally we have seen one science assist another in the way suggested. Thus the optician, especially after the invention of the telescope and of spectacles, pressed upon the attention of the physiologist that the living eye must possess the power of adjusting its focus to the vision of objects at different distances. And after some two centuries of unsuccessful endeavours to solve the problem, but not without the discovery of many important truths, in their efforts at its solution, the physiologists of our own day have within the last three years justified the optician by solving the problem, and have added largely to the wealth of their own science.

If there are few such cases, it only shows how much more difficult it is to reason deductively than inductively, and how very rarely man can look down from a point of view, even faintly approximating to that at all times occupied by God, and see a law go forth to its fulfilment.

And therefore before seeking to reach the last conclusion to which our method of inquiry may lead us, I would pause to notice the lesson which it teaches of humility and patience. Kepler, the astronomer, when he could not convince his contemporaries that the laws which he had announced as presiding over the movements of the heavenly bodies did actually exist, nobly consoled himself with the reflection that if God had waited some six thousand years before He could find one man to believe that He had impressed such laws on the planets, Kepler might well wait one year before blaming his fellow-men for not believing him. If God, in like manner, has waited not thousands, but millions of years, before a very few of His children have studied His works, so as to learn, even most imperfectly, why He made them and their pre-Adamic ancestors of one kind of dust, rather than of another, we need not boast of the little we know,

or angrily complain, because our small discoveries about fluorine, or the like, do not seem to others quite so wonderful as they do to ourselves.

With no desire, accordingly, to be dogmatic, or to press for a verdict in favour of my conclusions, I refer to the truths (in so far as they are truths) expounded in the preceding pages as *illustrations*, not *demonstrations* of final causes. To a belief in these no man can compel another, and I would not compel another even if I could. I blame no man for disbelieving them ; but I should be glad to secure for all, the happiness which faith in them begets. The doctrine of final causes is at present in disrepute in many scientific quarters, and this can neither be wondered at, nor in many cases much condemned. There have been so many unwise endeavours to sustain this doctrine, by arguments of less than no value, that it has been unavoidably discredited and despised.

All lovers of truth will join in protesting against making a search for final causes, the chief object of scientific inquiry. We are certain to be misled if we do. There are idols of the church, as dangerous as those idols of the den or of the market-place against which Bacon so specially warns us. But when guided by the *Lumen Siccum*, which a desire for the simple truth supplies, we have patiently and honestly reached a result, and then find our hearts swelling with rapture at the wondrous example which it affords of God's wisdom and power, we are traitors to ourselves and to our Maker if we refuse adoration.

I believe that few honest intellects and hearts can come face to face with such truths as I have most imperfectly detailed in these pages, without in the beginning feeling a great doubt of their reality, and in the end a great faith in them ; and I know that, like St. Thomas of old, they will

first stand up, and thrust their fingers into the nail-marks on the palms, and their hands into the hole in the side; but by and by they will kneel and say, 'My Lord and my God!' If some are faithless, I will ask them to look at the Great Panorama with beating hearts, as well as with eager eyes, and I will simply sorrow for them if they think to measure the universe by the intellect and the senses. I follow with unbounded delight and gratitude, though it is at a long distance, the footsteps of the great Philosopher Humboldt, when he goes before me round the vast Cosmos, and with infant-like simplicity shows me every known feature of universal nature, without speculation on its purpose or cause. But I have no sympathy with the Man Humboldt when he tells me that our most reverent demeanour towards God, is that of not pretending to discover purposes of one kind or another in any of His works; so that we should imitate the ancient Egyptians who showed their special reverence for Osiris by never naming him. The only attitude that befits us as men, after traversing a mere fraction of the Cosmos, is that of kneeling worshippers.

Nor need we be ashamed to be seen on our bended knees, because Final Causes are so often foolishly dealt with by their admirers. They always will be by a large class. Few realize what the words Final Cause mean. To demonstrate the full reason or entire Final Cause, why one element, such as iron, exists in the body, would demand a perfect acquaintance, not only with all the properties of that element, but with all those of every other element which is also present in the body; besides an acquaintance with much else: and how little do all the chemists of the world know even of a single element!

The sagacious old alchemist, Basil Valentine, in his famous *Currus Triumphalis Antimonii*, in which he has

triumphantly ridden down to the present day, and is likely to ride for many a day to come, declares that 'no man knows all the virtues of Antimony.'[1] With what astonishment would Basil, if he could revisit the earth for half an hour, hear of antimonious, antimonic, and metantimonic acids; of antimoniuretted hydrogen, penta-sulphide of antimony, stibio-methyle, stibio-ethyle, and the like. The coaches of his day did not differ more from the railway carriages of ours, than his 'Currus Triumphalis' does from such a Triumphal Chariot of Antimony as Hofmann, if he chose, could mount upon literary wheels at the present day. Yet Hofmann would find no better motto to put upon the panel of his chariot than Basil's words, 'No man knows all the virtues of Antimony,' and I may add, no man ever will; nor is the chemist better off in respect to other things than he is in respect to Valentine's favourite metal.

What we call a final cause, is not God's final cause, but only that small corner of it which we can comprehend in our widest glance. The fragmentary corner fills our intellects, not because it is vast, but because they are small, and we find how small they have made it, the moment we try to make the fragment a measure of infinite wisdom. The wisest of us is but a microscopic shell in the ocean of Omniscience, and when left on the shore with a drop of its waters in our cup, we cannot reflect in its tiny mirror more than a drop's worth of the meaning of the universe. And yet we speak as if out of that drop the whole universe might

[1] Basil's own words, as given in the quaint translation printed in London for Dorman Newman at the King's Arms in the Poultry, 1678, run thus:—'*Antimony*, like unto *Mercury*, may fitly be compared to a round circle, of which there is no end; in which the more diligently any man seeks, the more he finds, if process be made by him in a right way and due order. *Yet the life of no one man is sufficient for him to learn all the mysteries thereof.*'—Basil Valentine, *his triumphant Chariot of Antimony, with Annotations of Theodore Kirkringius, M.D.*, p. 19.

arise! Men of cold, logical intellect have so fully realized this, that on all hands they remind students of science that Bacon declared final causes to be sterile, comparing them to nuns or vestal virgins dedicated to God.[1]

I accept Bacon's statement, and still more his comparison. He is held by most who quote his famous condemnation of final causes to have pronounced them *essentially* unfruitful; but if he did not intend simply to signify that they are unfruitful to *man*, he could not have chosen a comparison better fitted to signify an unfruitfulness which was of extrinsic, not intrinsic origin.

Final causes are sterile, not merely like as, but for the same reason as, the Vestal Virgins were, namely, because they belong to God. These virgins, as well as others, might have become mothers; but no man dare wed them, for they were God's Brides. Neither can any man mate with final causes: they will bear no offspring to him. And exactly for that reason are they the most perfect of earthly witnesses

[1] 'Nam *Causarum Finalium* inquisitio sterilis est, et tanquam virgo Deo consecrata nihil parit.'—*De Augmentis Scientiarum*, lib. iii. cap. v. Since writing the text, I find that in the elaborate edition of Bacon's works, of which the first volume has just issued from the press, under the editorship of Messrs. Spedding, Ellis, and Heath, this passage is commented on as follows:—'No saying of Bacon's has been more often quoted and misunderstood than this. Carrying out his division of the *Doctrina de Naturâ*, which, as we have seen, depends upon Aristotle's quadripartite classification of causes, he remarks, that to Physica corresponds Mechanica, and to Metaphysica, Magia. But Metaphysica contains two parts, the doctrine of forms and the doctrine of final causes. Bacon remarks that Magia corresponds to Metaphysica, inasmuch as the latter contains the doctrine of forms, that of final causes admitting from its nature of no practical applications. 'Nihil parit,' means simply, 'non parit opera,' which, though it would have been a more precise mode of expression, would have destroyed the appositeness of the illustration. No one who fairly considers the context can, I think, have any doubts as to the limitation with which the sentence in question is to be taken. But it is often the misfortune of a pointed saying to be quoted apart from any context, and, consequently, to be misunderstood.'—P. 571.

to the being and perfections of God. Gentle, solemn, and beautiful, they attract men, and modestly permit them to look on their features; but awe mingles with admiration in the gazer's heart, and the ever-burning fires on the vestal altar forbid all close or impious approach. Nevertheless, we must seek after, and love final causes, even with a lover's passion, although in this life they never can be ours. An irresistible impulse compels us to cling to them. It would be a proof of insanity if we were only mortals; as would also be that attempt to be omniscient, which is the constant, though often unconscious aim of every student. But both are the most natural and irrepressible instincts of immortals, who look forward, through God's mercy, to all eternity as their time of studentship, and to all His infiniteness as the object of their study. For such the contemplation of final causes will never end, any more than it will ever beget satiety.

ROBERT BOYLE.[1]

It is reported of Thomas Carlyle that he once half-jestingly declared his intention of writing a life of Charles the Second, as one who was no sham or half man, but the perfect specimen of a bad king. Charles, however, if he did no other good thing, founded the Royal Society, and by so doing saved his portrait from being cut out in untinted black, by the stern humorist's scissors.

The thoughtless monarch, no doubt, did as little for science as he well could. The only incident in his life which can be referred to as indicating a personal interest in it, is his sending the Society a recipe for the cure of hydrophobia, but the act was probably prompted as much by his love of dogs as his love of science. Sheer carelessness on his part appears to have been the cause of the

[1] (1.) *A History of the Royal Society, with Memoirs of the Presidents.* By Charles Richard Weld, Esq., Barrister-at-Law; Assistant Secretary and Librarian to the Royal Society. In 2 vols. London: John W. Parker, West Strand, 1848.

(2.) *Occasional Reflections.* By the Hon. Robert Boyle. J. H. Parker, Oxford and London, 1848.

(3.) *Boyle Lectures for* 1846. By Frederick Denison Maurice, M.A., Chaplain of Lincoln's Inn, and Professor of Divinity in King's College, London. London: John W. Parker, West Strand. Second Edition, 1848.

(4.) *A Sermon, Preached January* 7, 1691-2, *at the Funeral of the Hon. Robert Boyle.* By Gilbert Burnett, D.D. Edited by John Jebb, D.D., F.R.S., Bishop of Limerick, Ardfert, and Aghadoe. London: James Duncan, 37, Paternoster Row, 1833.

Society's not obtaining confiscated lands in Ireland, which he was willing it should possess, and which would have ultimately yielded an ample revenue. The members besought him for apartments where they might meet and keep their library, curiosities, and apparatus. Charles at last gave them a dilapidated college and grounds at Chelsea; but, characteristically enough, it turned out that the property was only in part his to give; and the Society, finding it had inherited little else than a multitude of lawsuits, was glad to restore the college to Government, and accept a small sum in exchange. Yet Charles did more for science, at a time too when royal patronage was a precious thing, than many wiser and better monarchs have done, and it would be difficult to discover any sinister or interested motive which the King had in assisting the philosophers. He probably did not pretend (except in the Society's charters, which in all likelihood he never read) to revere science as Truth, or covet it as Power, but he could wonder at it as Marvellous. It dealt in novelties, and he was too intelligent and inquisitive not to be struck by them. It helped him through a morning, to attend on occasion 'an anatomical administration' at Gresham College, and see an executed criminal dissected. From time to time also, the members of the Royal Society showed him their more curious experiments, and Charles first smiled approbation, and then generally found something to laugh at, either in the experiment or the experimenter. It occasioned him no little diversion, as we learn from Pepys, to witness the philosophers 'weighing of ayre.' He had too strong and practised a sense of the ludicrous not to be keenly alive to the little pedantries and formalities of some of the fellows; and too little reverence in his nature to deny himself a laugh at their weakness and follies. He was sometimes,

no doubt, entitled to his smile at the experimenter; and always, if he saw fit, at the experiment. For everything on this earth has its ludicrous as well as its serious aspect, and the grave man need not grudge the merry man his smile at what he thinks strange.

An experiment, too, was a thing on the result of which a bet could be laid, as well as on the issue of a game at cards or a cock-fight. The Royal Society was, on one occasion, instructed that 'his Majesty had wagered £50 to £5 for the compression of air by water.'[1] A trial, accordingly, was made by one of its most distinguished members, and the King, as may be surmised, won his wager.[2]

It is impossible to read the histories and eulogies of the Royal Society, without detecting in them, in spite of all their laudations of its kingly founder, a subdued but irrepressible conviction, that by no address of the annalist can Charles II. be made to figure as an august patron and promoter of science. It is not that he will not brook comparison with such princes as Leo X., or the Florentine Dukes. Charles could not be expected to equal them, but he took such pains to show that he had the progress of science as little at heart as the maintenance of personal virtue, or public morality, that he has baffled the most adroit royalist to say much in his praise. He was often expected at the public meetings of the Society, but he never accomplished an official visit. He dreaded, no doubt, the formality and tediousness of the *séance*, and his presence might have recalled the caustic proverb, 'Is Saul too among the prophets?'

Nevertheless, it might have fallen to the Royal Society's lot to have had a worse founder. Its seeds were sown, and had even germinated in the days of James I., but the

[1] Weld, vol. i. p. 231. [2] *Ibid.* p. 232.

philosophers were fortunate in escaping the patronage of the most learned of the Stuarts. James would have plagued them as much as Frederick the Great did the *savans* he favoured. His sacred Majesty would have dictated to the wisest of them what they should discover, and how they should discover it. A wayward genius like Hooke would have paid many a visit to the Tower, or one to Tower Hill; and any refractory philosopher who persisted in interpreting a phenomenon otherwise than the royal pedant thought he should interpret it, would have been summarily reminded of the 'King's divine right to rule,' and treated as a disloyal subject.

Charles I., we can well believe, looked on with unassumed interest at Harvey's dissection of the deer's heart, and demonstration of his great discovery of the circulation of the blood. Whatever that monarch's faults may have been, he had too religious a spirit not to have honoured science, and too kingly a manner to have insulted its students. But his patronage would have compromised the liberties and lives of the philosophers during the civil war, and we should grudge now if the perversest cavalier among them had paid with his life for his scientific royalism.

The uncrowned king that followed the first Charles, had his hands too full of work, and his head and heart too much occupied with very different things, to have much patience with weighers of air, or makers of 'solid glass bubbles.'[1] But a hint that they could have helped him to a recipe for 'keeping his powder dry,' or improved the build of his ships, or the practice of navigation, would at once have secured the favour of the sagacious Protector. When the Restoration came, however, such services to Cromwell

[1] 'Rupert's Drops,' Weld, vol. i. pp. 103, 113.

would have procured for the philosophers a swift and bloody reward.

Things fell out, as it was, for the best. The infant Society escaped the dangerous favours of King and Protector, till the notice of royalty could only serve it: and then it received just as much of courtly favour as preserved it from becoming the prey of knavish hatchers of sham plots, and other disturbers of its peace; and so little of substantial assistance that its self-reliance and independence were not forfeited in the smallest. Charles the Second did the Royal Society the immense service of leaving it to itself, and an institution numbering among its members such men as Newton, Boyle, and Hooke (to mention no others), needed only security from interruption, and could dispense with other favours. And it had to dispense with them. The title of the Society is apt to convey the impression that it had the Government to lean upon, and was dowered from its treasury. But this was not the case. The Society was not fondled into greatness by royal nursing. Charles's only *bonâ fide* gift to it, was what Bishop Horsley, in an angry mood, denounced as 'that toy,' the famous bauble mace, which the original warrant for its making, calls 'one guilt mace of one hundred and fifty oz.'[2]

In return for this benefaction the Society presented their patron with a succession of remarkable discoveries and inventions, which told directly on the commercial prosperity of his kingdom. The art, above all others the most important to this country, navigation, owes its present perfection in great part to the experiments on the weight of the air, and on the rise and fall of the barometer, to the improvements in time-keepers, and the astronomical discoveries and observations, which Boyle, Hooke, Newton,

[1] Weld, vol. ii. p. 168. [2] *Ibid.* vol. i. p. 163.

and other members of the Royal Society made during Charles the Second's reign. The one hundred and fifty ounces of silver gilt were returned to the treasury in his lifetime.

In exchange for the regal title which they received, the Society made the monarch's reign memorable by the great discoveries which signalized that era, and under his nominal leadership won for him the only honourable conquests which can be connected with his name. Estimated in coin, or in honour, given and received, the king stands more indebted to the Society than the Society to him.

We will not, however, strive to lessen Charles's merit. The gift of the mace, 'bauble' though it was, may be accounted a sincere expression of goodwill. It probably appeared to the donor an act of self-denial to let so much bullion of the realm go past the profligates of both sexes, who emptied his pockets so much faster than he could fill them; and the deed may pass for a liberal one. We willingly make the most of it. Charles the Second's reign is, from first to last, such a soiled and blotted page, that we are thankful for one small spot, which, like the happy ancients, we can mark with white. CAROLUS SECUNDUS REX, we think of with contempt, and loathing or indignation; but Charles Stuart, F.R.S., meant on the whole well, and did some little good in his day.

Charles's connexion with the Royal Society, however, is a small matter in its history. He was its latest name-giver, not its founder. If any single person can claim that honour, it is Lord Bacon, who, by the specific suggestions in his *New Atlantis*, but also, and we believe still more, by the whole tenor of his *Novum Organum*, and other works on science, showed his countrymen how much can be done for its furtherance, by the co-operation of many labourers.

But even Bacon must share the honour with others; learned societies are not kingdoms which the monarchs of intellect found; but republics, which grow out of the common sympathies of many minds. Fraternity is the rule, though not equality, and there is no prating about liberty, for it is enjoyed by all.

A Bacon or a Descartes does not act on his fellows like a great magnet attracting to itself all the congenial metal within its range. A brotherhood grows as a crystal does. Particle seeks out like particle, and the atoms aggregate into a symmetrical whole. The crystal, when completed, has not the same properties in every part, but it is not the presence of a peculiarly endowed molecule at the centre, or the summit, that occasions the difference.

It seems a vain thing, accordingly, to insist on singling out individuals, however gifted, as the founders of learned 'bodies.' The very title we apply to them might show us the folly of it. 'The body is not one member, but many.' It was not the brain that produced it, nor the heart, although it may be true that these were first and fullest developed, and were essential to the knitting together of the weaker and less vital members.

The association of gifted men, which afterwards became the Royal Society, rose into being simultaneously with many similar institutions in other parts of Europe. These were not copies of each other, but originated in the kindred sympathies of their several founders. Why such societies should have sprung up in the seventeenth century, and not earlier, or later, is a question not to be answered by any reference to any single cause. It will not solve the problem, to say that Bacon was born at a certain epoch, or Galileo, or Newton. The birth of those and other great men, is as much part of the phenomenon to be explained, as the ex-

planation of it. Neither will the invention of printing, nor the outburst of the Reformation, supply more than a part of the rationale. What we have to account for is this :—Mankind stood for ages, with closed eyelids, before the magnificence of un-ideal nature, or opened them only to gaze at her with the eyes of poets, painters, and mystics. They saw wondrous visions, and clothed nature with splendid vestments, which they wove for her. All at once they bethought themselves, that the robes which God had flung over the nakedness of the material world, might be worth looking at, and might prove a more glorious apparel than the ideal garments which man's imagination had fashioned for the universe.

The sleep of centuries was broken in a day. The first glances at the outer world were so delightful, that the eye was not satisfied with seeing, nor the ear with hearing. Men longed to extend their grasp beyond the reach of the unassisted senses. Within a few years of each other, the telescope, the microscope, the thermometer, the barometer, the air-pump, the diving-bell, and other instruments of research, were invented and brought to no inconsiderable perfection. The air, the earth, the sea, the sky, were gauged and measured, weighed, tested, and analysed. The world had been satisfied for hundreds of years with the one half of the Hebrew monarch's proverb, 'It is the glory of God to conceal a thing.' The verse was now read to the end, 'but the honour of kings is to search out a matter.'

The searching out of the willingly-divulged secrets of nature was not delayed till the seventeenth century, because none but Bacons, Newtons, Galileos, Descartes, and Pascals were competent to the task. We need not ask whether men of as ample, or exactly the same gifts, had preceded those great ones. It is certain that men with

endowments, liberal enough to have discovered much, if not all, that has been left for us and our immediate forefathers to find out, adorned even the darkest epoch of the earlier ages. Among the astrologers and alchemists were men of such rare genius, that, if by some choice anæsthetic they could have been flung into a trance, and kept pleasantly dreaming of 'the joy of Jupiter,' and the elixir of life, till the present time, they would awake to dispute the palm with our Herschels and Faradays. We will attempt no other explanation of the sudden, universal, and catholic recognition of the interest and importance of physical science, which characterized the seventeenth century, than this,—that mankind, as a whole, is possessed of a progressive intellectual life, which, like organic life, is marked at intervals by sudden crises of permanent expansion. The seed shoots forth the germ ; the petals blow into the flower ; the chrysalis bursts into the butterfly. The boy starts into the youth ; his thoughts are elevated, his desires changed ; and so the whole race, in a brief interval of time, is lifted to a higher intellectual level, and its speculations directed into new channels.

The aloe buds, thorns, and leaves only for ninety-nine years, and we have to wait till the hundredth comes, before the flower blooms. The flower is not an accident of the hundredth year, but its complement and crown. Had the thorns not protected the leaves, and the leaves elaborated the juices during the ninety-nine barren years, the century would not have been crowned by the flower. Yet why the aloe blooms in its hundredth rather than in its fiftieth or its tenth year, is not explained by this acknowledgment.

The contest between Charles the First and the English people, was contemporaneous with an aloe-flowering of the genius of the nations of Europe. It was no accident or

mere result of a certain century having arrived. The printing-press, and the Reformation, the births of great men, and much else, were its thorns and leaves, and wide-spread supporting roots; but we cannot say, *therefore*, the revolution in men's scientific tastes occurred after 1600, rather than after 1500 or 1700, any more than we can demonstrate that 1848 was the necessary and infallible year for the overturning of the thrones of Europe.

The Royal Society was one of the choicest buds of this blossoming of the European intellect. Its beginnings were some two hundred years ago, about 1645, when 'divers ingenious persons' met weekly in London, to make experiments and discuss the truths they taught. 'We barred,' says Dr. Wallis, one of their members, 'all discourses of divinity, of state affairs, and of news, other than what concerned our business of philosophy.'

About the year 1648-49, some of their company removed to Oxford, upon which the Society, like a polypus, divided itself into two. The one half, provided with a new tail, remained in London, the other, furnished with a new head, throve at Oxford. It was afterwards matter of dispute which was the better half, but we need not discuss the question. The halves came together in London, and after Charles the Second's return, 'were, about the beginning of the year 1662, by his Majesty's grace and favour, incorporated by the name of the Royal Society.' It had no fixed title before its incorporation. Boyle spoke of it as the 'Invisible College.' Evelyn wrote of it as a 'Philosophic Mathematic College.' Cowley called it the 'Philosophical Colledge.' Only sickly infants are christened in haste. It was an earnest of the Royal Society's longevity that it had long been weaned, and was out of leading-strings, before it was named.

Four histories of the Society have been published. We have placed at the head of our article the title of the last and best. It is a pleasant volume, which all classes of our readers may peruse with interest. Mr. Weld's position, as Assistant-Secretary of the Royal Society, has given him unrestrained access to its archives, so that he has always been able to refer at first hand to original and authentic documents. His duties bring him in contact with our most distinguished men of science, whom he has had the constant opportunity of consulting on the many difficult scientific questions he has had to discuss. Himself an accomplished barrister, he weighs conflicting evidence with the nice discrimination of an enlightened lawyer and impartial judge; and making no pretensions to the title of philosopher, he estimates the merits of scientific men without any of the bias which attaches to their estimate of each other. His point of view is that of a literary man interested in the progress of science, but having no personal stake in the solution of its problems, or the award of its honours. Four years have been spent by Mr. Weld in preparing his work, which has cost him much tedious ransacking of the treasures of the British Museum, Bodleian Library, State Paper and Lord Chamberlain's Office, as well as the Collections of the Royal Society. His time and labour have not been thrown away. New light is cast, by his researches, on many epochs in the Society's history, which we had thought destined to remain for ever in impenetrable obscurity. Short Lives of all the Presidents are given, written on the whole pleasantly, and relieved from stiffness by characteristic anecdotes. Famous Fellows, though not Presidents, come in for a share of Mr. Weld's biographical notices; and as the History approaches our own times, the interest of the work in this respect greatly increases. The author's zeal, indus-

try, and discrimination, have enabled him to enrich his work with curious unpublished particulars concerning Sir Joseph Banks, Franklin, Priestley, Rumford, Watt, Cavendish, Young, Wollaston, Davy, Herschel, Faraday, which will prove of no little value to the biographers of these great men.

Few sources of information have been neglected by Mr. Weld. This Journal has not been overlooked, and here we have to find our only fault with our author. In the sketch which he has given of Dr. Wollaston, he has availed himself freely of a notice of that philosopher which appeared in this Review,[1] and has referred to certain of its judgments with approval. Mr. Weld, however, has failed, and that designedly, to mention from what work he quoted. At first we thought that the statement on the title-page of the 'History of the Royal Society,' that it is 'compiled from *authentic* documents,' might be intended to exclude, as unauthoritative, the anonymous articles of a periodical journal. But Mr. Weld is above this affectation. He invariably acknowledges his obligations to some other sources of this description, when information is borrowed from their pages. The same justice should have been shown to us. If our opinions were worth quotation and adoption, their source was worth acknowledging. When the official representative of our greatest scientific society is deliberately guilty of plagiarism from our pages, we cannot wonder that minor appropriators steal from us without blushing.

We cannot leave Mr. Weld's volumes without reminding our readers that the 'History of the Royal Society' is a part of the History of the Empire. For nearly two hundred years it has gathered together one great division of the highest intellects of the nation, and given unity and a prac-

[1] *British Quarterly Review*, No. VII. p. 81. The sketch of Wollaston referred to, is that which comes next in order in this volume.

tical aim to their labours. All its doings have not been wise, or its works fruitful. But its errors have been singularly few, and its most abstract, and apparently visionary occupations have, in the great majority of cases, been found, in the end, ministering to the welfare of all men. It has expanded the intellect of the whole people; been the true, though sometimes unconscious and generally distrusted ally of Religion; and the faithful, though too often unthanked servant of Government, which it has aided and guided in increasing the commercial and political greatness of the country.

The Society will never be thanked as it deserves for its direct services to the empire, much less for its indirect ones. It is not that men are unthankful, but that they are slow to perceive that there is occasion for thanks, and they are blind to their true benefactors. Rarely does a scientific inquiry like Davy's 'Researches on Flame,' bud, blossom, and bear fruit, like Aaron's rod, in a single night, and show forth, on the morrow, a Safety Lamp, the value of which men hasten to acknowledge by cheques on their bankers, and a service of plate to Sir Humphry. In general, one man sows and another reaps; the acorn is planted in this age, and the oak felled in the next. The seed-time is forgotten before the harvest comes. Too often, also, while the sower was a very wise man, the reaper is only a very needy or greedy one. He puts a money value on the grain, which the public pays, and cries quits. It would be difficult to extort from many a London or Liverpool shipowner an acknowledgment that the Royal Society did him a service by persuading Government to spend a round sum of money in sending out vessels to observe the transit of Venus over the sun's disk. It would be still more difficult to persuade him that he owed thanks to the astronomers of Charles the

Second's reign, for watching, night after night, the immersions and emersions of Jupiter's moons; that Dr. Robert Hooke was his benefactor, by experimenting upon the properties of spiral springs, and Dr. Gowan Knight by making artificial magnets. The shipowner furnishes his captains with Nautical Almanacs, chronometers, and compasses, and thanks no one. The bookseller and instrument-maker have got their own price for their goods. Business-men do not thank one another when value is given for value. All London has been out gaping at the new electric light. It has gone home with dazzled eyes, not to meditate statues to Volta, or Davy, or Faraday, but to reflect that the light is patent, and must be paid for, and to consider the propriety of disposing of its shares in the gas companies, and retiring from the oil and tallow trade.

We do not make these remarks complainingly. Scientific men have, at present, a fair share of the sympathy and gratitude of their unscientific brethren, and are every day receiving fuller and more kindly acknowledgment of the value of their services.

Whilst we are writing, Mr. Macaulay's eloquent recognition of the debt of gratitude which the nation owes the Royal Society has appeared, to wipe away its reproach among the ignorant. He must be an exacting man of science who is not satisfied with the graceful tribute to the worth of his labours which a great literary man has so willingly paid.

We have spoken of the past glories of the Royal Society, but though its history has been four, we may say, five times written, it has not become an historical thing. It never ranked a greater number of men of genius among its Fellows than it does at present, and we trust that the time is far distant when the Society shall end with the name with

which it began, and become, in sad earnest, the Invisible College.

Three of the earliest members of the Royal Society distinguished themselves from the other Fellows by the innumerable additions which they made to natural knowledge, or, as we should now call it, physical science. These were Isaac Newton, Robert Hooke, and Robert Boyle. The last is to be the special object of our further remarks. In genius he was the least of the three, but to be least in that triad was to be great among ordinary men. He comes before his greater brethren in point of time. He was older than Newton by fifteen years, and older than Hooke by nine. Newton wrote to Boyle as to a grave and reverend senior, and Hooke, who in early life was his experimental assistant, displayed to his old master a love and esteem such as he exhibited to no other philosopher. It was long ago observed that Boyle was born in the year in which Bacon died, and it soon appeared that a corner, at least, of the deceased prophet's mantle had fallen upon him. He was the earliest pupil who applied, in practice, the lessons of the *Novum Organum;* the oldest, though not the greatest of the Marshals, who won for himself a kingdom, by following the rules of conquest laid down by the Imperial Verulam. As the patriarch, therefore, of English experimental science, he takes precedence even of Newton.

It is in this capacity that we propose chiefly to treat of Boyle. He was too memorable a man, however, in other respects, not to require his whole character to be sketched, though it can be only in outline. Many excellent biographies of him have appeared, but no recent English writer has given an analysis of his scientific researches, so that a good purpose may be served by giving an abstract of certain of the more important of them, with an estimate

of their value, as examined by the light of a science, much of which is two centuries older than that of Boyle's time. He is eminent as a discoverer in chemistry, heat, pneumatics, hydrostatics, and various other branches of physics proper. He was one of the great improvers of two of the most important instruments used in scientific researches—the air-pump and the thermometer. He was a zealous naturalist; an active medical practitioner, and so good a theologian and excellent a Christian, that Lord Clarendon would gladly have assured him of a mitre, could he have persuaded him to enter the church. In all those respects we shall have something to say of him, but it is of Boyle the philosopher we have chiefly to speak.

The Honourable Robert Boyle was the seventh and youngest son of Richard Boyle, first Earl of Cork, known in his day as the Great Earl, so remarkable had been his rise from a lowly station to the possession of great wealth and dignities. He landed in Dublin to seek his fortunes in 1588, the penniless and untitled younger son of a younger brother; and in 1632 he was entitled to style himself 'Sir Richard Boyle, Knt., Lord Boyle, Baron of Youghall, Lord Dungarvan, Earl of Cork, Lord High Treasurer of Ireland,' etc. etc. He had ample wealth also to support his titles. Through prudence, good management, and friends at court, he procured grants and favourable bargains of confiscated Irish estates, and his wealth enabled him to purchase property in England, so that he ultimately became one of the largest landed proprietors in the empire. His greatness is now almost entirely forgotten, or remembered only in connexion with the more enduring fame of his sons, Roger (Lord Broghill, afterwards Earl of Orrery), and the subject of our sketch. The Earl's name deserves to be connected with those of his children. He was an upright,

estimable man, and a kind considerate father. Boyle was indebted to him for a most liberal education, and for the fortune which enabled him to devote himself to science.

The particulars of Boyle's early years have been chronicled in a curious autobiography, in which he speaks of himself in the third person, under the assumed name of Philaretus. As it acquaints us with the chief particulars of his life nearly up to the period when he commenced his scientific researches, we shall go briefly through its personal revelations, before saying anything concerning his labours as a discoverer in physics.

Boyle was born at his father's country seat of Lismore, in Munster, on the 25th day of January, 1626 (o.s.)[1] The Earl of Cork, as his son tells us, 'had a perfect aversion for their fondness who used to breed up their children so nice and tenderly, that a hot sun, or a good shower of rain, as much endangers them as if they were made of butter or of sugar.' As soon, therefore, as the baby Philaretus 'was able, without danger, to support the incommodities of a remove,' he was sent to a country nurse, and inured to plain fare and homely ways. Boyle thought he profited much by this regimen, though to appearance, in after life, he did little credit to his country nursing, for he was a sickly valetudinarian all his days. Yet as he nearly made out the allotted three-score years and ten, in spite of several sharp illnesses, and much swallowing of his own physic, it is likely that he owed something to his rustic cradle.

Before he could appreciate the greatness of the calamity, which, however, he reckoned amongst the chief misfortunes of his life, he lost his mother, a woman of a free and noble

[1] The *Biographia Britannica* says February, and gives authorities for its statement. Boyle's father says January.—(Earl of Cork's 'True Remembrances,' printed in Introduction to Birch's *Life of Boyle*.)

spirit, and rich in the possession of many virtues. Some of the more glaring defects which marred his intellect in manhood, may be traced indirectly to this misfortune. The widowed Earl transferred the love he had felt for the mother to the motherless boy, whose sweet disposition was not altogether proof against the injurious effects of his father's double love. Philaretus dwells with a natural complacency on the fondness felt for him by the 'good old Earl;' and moralizes in his own fashion on the causes of it. He refers it partly to his being, like Benjamin and Joseph, the son of the Earl's old age; partly to a likeness observed in him 'both to his father's body and his mind,' but chiefly, as he cynically enough conjectures, 'to his never having lived with his father to an age that might *much* tempt him to run in debt, and take such other courses to provoke his dislike, as in his elder children he severely disrelished.' The evil result of this indulgence may be surmised. Boyle got a great deal too much of his own way. He was, what is emphatically called, a 'spoiled child.' His studies and his masters were often changed. He went through no systematic or severe scholastic or academic training, but roved in a desultory way over the whole field of knowledge. He had a quick, versatile intellect, but he was not a deep thinker; so he learned many things, but none profoundly. His Autobiography and his voluminous works, show him to have been, in all things but religion, an amateur from the cradle to the grave. Boyle confessed in after life to being much afflicted with a 'roving wildness of wandering thoughts,' which he amusingly and unreasonably imputed to his having been allowed, when a schoolboy, during convalescence from sickness, to read *Amadis de Gaule*, and other fabulous and wandering stories. He sought to cure the evil by 'the extraction of the square and cube roots,' which he found the

most effectual remedy for his 'volatile fancy.' The cure was an exceedingly imperfect one, for few productions of able men exhibit less of logical method, orderly arrangement, and terse condensation, than Boyle's works, although they are not wanting in clearness or graphic power. In last century Johnson affirmed, that many talked of Boyle, and praised him, but that nobody read his books; nor have the readers increased since Johnson's time. The tide is now setting in in favour of reprints, and Boyle has not been overlooked. His *Occasional Reflections* have been re-issued, with what result we shall see.

Boyle, however, was no ordinary amateur. He displayed, while yet very young, a precocity of intellect, and a gravity and even melancholy rare in a child; he showed, what is still rarer in children, especially spoiled children, a regard for truth, which was proof against every temptation. He never told a lie.

Having learned before he was eight years old to write a fair hand, and to speak French and Latin, he was sent in his ninth year to Eton College, where he remained nearly four years, and was allowed many indulgences. His aptness and willingness to learn procured for him here the special attention of one of the masters, Mr. Harrison, who instructed him privately and familiarly in his chamber, in 'an affable, kind, and gentle way.' This kindly teaching acting on a genial disposition, awoke in the eager boy a passionate desire for learning. Like many other great readers, he referred his love of books to the study of a single remarkable one in early life. The volume in this case was Quintus Curtius, the accidental perusal of which, at Eton, 'first made him in love with other than pedantick books, and conjured up in him that unsatisfied appetite of knowledge that is yet as greedy as when it was first raised.' Boyle,

we may be certain, mistook the nature, though not perhaps the extent of the influence of Quintus Curtius upon him. The 'Faëry Queen' did not make Cowley a poet, but only revealed to him that he was one. Had the unsatisfied appetite of knowledge not existed in Boyle's mind, before he fell in with Quintus Curtius, Quintus would never have been read. It did not beget the love it seemed to create, but only made its reader fully conscious of a passion that had long and silently been growing up within him. From that moment, however, it burned with a double glow.

A schoolboy's journal cannot be expected to record many incidents which shall seem memorable to others. We select from Philaretus' school life only such particulars as throw light on the tastes and labours of his manhood. Passing over, therefore, the recital of several narrow escapes from death, we halt for a moment at a tedious account of his life being perilled, whilst at Eton, by an emetic administered to him in place of a refreshing drink. The mistake was owing to an apothecary, and Boyle was more frightened than hurt. It gave him, however, a dislike to mediciners of all degrees. He pungently remarks, that 'this accident made him long after apprehend more from the physicians than the disease, and was possibly the occasion that made him afterwards so inquisitively apply himself to the study of physic, that he might have the less need of them that profess it.' When he became his own master, accordingly, he dosed himself, and was, like most other amateur doctors, a very unhesitating practitioner.

Soon after this came a journey to London to interrupt his desultory studies, a tertian ague to interrupt them still further, and, worst of all, the reading of *Amadis de Gaule*, already referred to, which, if Boyle's hypothesis were true, gave so incurable a bias to his roving fancy. Scarcely had

he recovered from the ague before his father arrived in England, and Boyle went to visit him. The old Earl soon found that he loved his favourite child too much to part with him again. He was taken from Eton accordingly, and resided with his father at Stalbridge, a country seat in Dorsetshire, which Boyle afterwards inherited. The latter had contrived, during his last year at Eton, to forget most of the Latin he had learned, in consequence of 'the change of his old courteous schoolmaster for a new rigid fellow.'

At Stalbridge, after a time, he was sent to reside with an old divine, the parson of the place, who instructed him 'both with care and civility.' Under his teaching he recovered his Latin, wrote French and English verses, 'and began' (which is not very credible) 'to be no dull proficient in the poetic strain.' He burned his verses when he came of age, because, countryman though he was of Shakspere and Spenser, and contemporary of Milton, he held that 'English verses could not be certain of a lasting applause, the changes of our language being so great and sudden, that the rarest poems within few years will pass for obsolete.' It would have been well if the unwise prophet had entertained the same fear of the enduringness of English prose, especially his own, and had spared posterity one, at least, of his five folio volumes.

A fresh change of masters now occurred. Boyle passed from the hands of the old divine to the care of M. Marcombes, an accomplished Frenchman; a shrewd, cynical man of the world, of the better sort; a soldier and a traveller, but not a profound scholar. With him Boyle spent a summer, reading the *Universal History*, and in conversation in French 'equally diverting and instructive, which was as well consonant to the humour of his tutor as his own.' We can imagine how the congenial tutor and

pupil got through the day. Monsieur Marcombes, who had the superintendence of Boyle's studies for several years, did his duties faithfully, but the lake could not rise higher than the fountain. An accomplished amateur himself, he made Boyle one; and teacher and scholar were content to be amateurs.

Their busy idleness was, for a season, exchanged for unpretending playing. The Earl of Cork, who was a great encourager of early marriages in his family, concluded a match, in the autumn of 1638, between his sixth son, Francis, a lad of eighteen, and a step-daughter of Sir Thomas Stafford, one of Queen Henrietta's maids of honour. Boyle accompanied his brother to London, where he was sent, in terms of the foregone conclusion, to pay his addresses to the lady. The suit prospered; the times were too unsettled for long courtships or protracted wedding ceremonies. The parties, after a short acquaintance, were publicly married at court, in the presence of Charles the First and his consort; and four days after the wedding, 'the bridegroom extremely afflicted'—the bride being left behind—and his unsympathizing brother greatly delighted, were 'commanded away to France.' They kissed their Majesties' hands; set sail on one of the last days of October 1638; and 'a prosperous puff of wind did safely, by the next morning, blow them into France.'

Their stay on the Continent was much longer than either the exiled bridegroom or Boyle anticipated or intended. Accompanied by M. Marcombes, the brothers travelled rapidly through Normandy, visited Rouen, Paris, and Lyons, and settled for a season at Geneva. Here Boyle studied, with little relish, logic and rhetoric, but was 'enamoured of those delightful studies, arithmetic, geometry with its subordinates, the doctrine of the sphere, that of the

globe, and fortification.' He also took lessons in fencing and dancing, and liked the first as much as he hated the last. He amused himself with 'mall, tennis (a sport he ever passionately loved), and, above all, the reading of romances.'

This brings us to the end of 1640, and brings Boyle to his fourteenth year. It marks an important era in his personal history—the crisis of a great change in his spiritual nature—which he afterwards spoke of as the most important event in his life. We pass it by unnoticed at present, as a consideration of Boyle's mere intellectual qualities will, on the whole, furnish us with sufficient means for estimating his merits as a man of science.

In 1641, Boyle left Geneva on a tour through the north of Italy, visiting, among other places, Verona, Padua, Bologna, Ferrara, Venice, and Florence. At Florence, he resided for a winter, studying 'the new paradoxes of the great star-gazer Galileo,' who died in the neighbourhood of the city whilst Boyle and his brother were there. After a short stay at Rome, they bent their way homewards, and arrived at Marseilles in the spring of 1642, intending immediately to return to England. Instead of bills of exchange, however, to enable them to complete their journey, they found letters from their father announcing the breaking out of the general rebellion in Ireland of 1641. The Earl of Cork immediately raised troops, put them under the command of his elder sons, and maintained the soldiers at his own charge. He was a punctual paymaster; and so completely were his available funds swallowed up by the demands of his troopers, that, although a few years before he had allowed his second son, Richard (Lord Dungarvan), a thousand pounds a year whilst on his travels, he could now with great difficulty send his two younger sons

two hundred and fifty pounds to bring them home. This pittance, however, never reached them. The agent in London to whom the remittance was intrusted proved unfaithful to his trust, and the disappointed young men had to return to Geneva, and become dependants on M. Marcombes' bounty. Here, such was the distraction of affairs in Great Britain, they waited in vain for nearly two years the arrival of supplies from England; till, despairing of relief, they contrived, by raising money on some jewels in their possession, to reach their native country about the middle of the year 1644. Boyle found his father dead, and himself left heir to what in the end proved an ample estate; but, at the period of his arrival in England, its value was nominal, and he could scarcely venture to call it his own. Everything was in confusion. He scarcely knew whither to turn, and was on the eve of joining the royalist army, when, by a fortunate accident, he fell in with his sister Catherine, Lady Ranelagh, with whom he resided for some months in London. A strong attachment, which lasted through life, subsisted between Boyle and his sister, who was twelve years his senior. She was a lady of great genius, courage, and piety, and is dear to every lover of letters, as having ministered to the comforts of Milton's old age. Besides her sisterly care of Boyle, and the happy influence she exerted upon his disposition, she was able to render him an important service in his worldly affairs. The majority of her relations were Royalists, but she was connected by marriage with some of the chiefs of the Parliamentary party; and, during the civil war, her interest was sufficient to secure her brother's Irish and English estates from confiscation or spoliation.

Boyle returned for a short time to the Continent in 1645, to arrange his pecuniary affairs; and it is not till 1646

(o. s.), or a little more than two hundred years ago, that, at the age of twenty, he began his scientific researches. His collected works, including his Life and Correspondence, occupy six large, closely-printed folio volumes. These have been edited by Dr. Thomas Birch, and will be referred to as 'Birch's Boyle:' the edition intended is that of 1772. His scientific papers alone occupy three formidable quartos, after having been largely abridged by Dr. Peter Shaw. The abridgment we shall distinguish as 'Shaw's Boyle:' the edition referred to is that of 1738.

It would be vain to attempt a systematic or chronological analysis of works so voluminous as those referred to. We must, with our limited space, be content to show what Boyle has done to extend pneumatics, and, more briefly, what he has achieved for chemistry, heat, natural history, and medicine. We select the subjects that have been least referred to in previous expositions of Boyle's labours, and of those we shall dwell chiefly on the first. Were we to attempt to discuss them all, we could only glance cursorily at each. Any one of Boyle's entire scientific investigations would equally well illustrate his intellectual qualities, and exhibit his modes of procedure as a physical inquirer. Chemistry was, on the whole, his favourite science, and would furnish the amplest illustration of his character as a philosopher. His merits and defects, however, as a chemist have been pretty fully canvassed and acknowledged, and the additions he made to the recorded facts of chemistry secure him a place in the history of that science. A late distinguished professor, indeed, guiltless of any purpose of jesting or playing upon words, once gravely summed up the memorabilia of Boyle's history in the singular epitome, that he was 'the son of the Earl of Cork and the father of modern chemistry.' He was the Mentor, however, rather than the

Ulysses of the chemistry of the seventeenth century, and neither made so many discoveries as many individuals among his successors have accomplished, nor showed the genius that they have displayed in bringing to light new phenomena and laws. He was more the critic and corrector of the false chemistry of his time than the leader of a new era. When he had overthrown the old science, and had cleared a space for a truer and nobler chemistry, he helped to lay the foundations of the new edifice. But he was so much occupied in preventing unwise architects from rebuilding the tottering walls he had pulled down, that he could do little himself towards forwarding the stately erections that should replace them, but supply materials for succeeding wise master-builders. His name, accordingly, occurs rarely in modern treatises on chemistry, much more rarely than in works on natural philosophy. Phosphorus, which he first introduced to the notice of English philosophers, but did not discover, has shed its radiance round his name for a century and a half, and has lighted it down to the present day. In addition to this, a certain noisome volatile compound of sulphur, hydrogen, and nitrogen, called of old 'the fuming liquor of Mr. Boyle,' still continues at times to offer up its sorry incense to his memory. But otherwise, his name is rarely referred to, except by professed historians of chemistry.

In natural philosophy, however, he retains, and will retain, a high place as an observer, especially in reference to pneumatics. The first to construct and employ an air-pump in England, a very little after the earliest air-pump had been constructed in Germany, his name is inseparably connected with a department of knowledge, which, dealing with the properties of the atmosphere, is indissolubly interwoven with every one of the physical sciences. We shall not,

therefore, convey to the reader a false impression of the kind of reputation which Boyle possesses at the present day, if we refer to him as a natural philosopher, rather than as a chemist, although, did our limits permit, we should endeavour to show that he has done more for chemistry than most of his successors give him credit for. It would be a vain task, however, to condense six goodly folios into a few pages, and we have this additional reason, and it is our chief one for selecting Boyle's pneumatics as the example of his scientific researches, that the early history of the air-pump in England has fallen into great and unaccountable confusion. The confusion is every day increasing, and cannot be remedied too speedily, so that a service will be rendered to present, as well as to past, science if we remove it. The subject, accordingly, is discussed somewhat fully in what follows.

Pneumatics as a science was little known to the ancients. An instrument corresponding to a very indifferent air-pump was constructed by Hero of Alexandria, in which an imperfect vacuum could be produced by sucking out the air from the interior of a vessel by means of the mouth. The Alexandrian air-pump may be seen, at the present day, in the hands of our nursery-maids who never heard of Hero or Alexandria. Children are amused by having a thimble or a nutshell made to cling to the skin, after the air has been withdrawn from it by the action of the lips and cheeks. The thimble or the nutshell vacuum is as perfect as Hero's can have been, and the mode of its production is probably as clearly apprehended in the nursery as it was in Hero's time, and for ages after. The Greeks and Romans had no air-pumps—not, however, because they had not sufficient ingenuity to devise and construct them, for they used pumps to raise water, and an air-pump, though the cause of its

efficiency in emptying a cavity of its contents is different, is merely a water-pump employed to withdraw air instead of water from a vessel. A false philosophy had taught them that nature abhorred a vacuum, so that a void was non-existent and impossible, and those who had no faith in the possibility of a vacuum were as little likely to try to produce one, as the scientific mechanicians of our day are likely to employ their ingenuity in endeavouring to realize perpetual motion. The world universally doubted or disbelieved that such a thing as literal emptiness could exist, till in the early half of the seventeenth century, Galileo's celebrated pupil Torricelli, demonstrated that it could. Nature may be truly said to abhor a vacuum, but she does not forbid one. A void is difficult to produce, and still more difficult to preserve. Absolute emptiness has perhaps never been realized, but a very near approach to it has been made, and the void may be retained for a long, though not perhaps for an indefinite, period. Torricelli's vacuum, which exists in the upper part of every barometer, was produced by filling with quicksilver a glass tube, shut at one end, and more than thirty inches in length. The open end was then closed with the finger, and the tube was inverted, and plunged with its mouth downwards below the surface of quicksilver contained in a basin. The finger was then withdrawn, the quicksilver immediately retreated from the closed extremity of the tube, which was held perpendicularly, and sank till it left a column of the liquid metal some thirty inches long. If the tube employed were three feet in length, a space six inches long would thus be abandoned by the mercury. This space, if the experiment were properly performed, was in winter as nearly as possible, a perfect vacuum. In summer, it contained a little of the vapour of mercury. In 1654, ten years after the Torricellian

vacuum had been first produced, the famous consul of Magdeburg, Otto von Guericke, remarkable as the inventor of the electric machine, as well as the air-pump, was led to the conclusion, whilst reflecting on Torricelli's experiment, that air in virtue of its elasticity would expand when relieved from pressure, and continue to abandon a hollow vessel connected with a pump put in action, till the vessel should become ultimately vacuous. After some preliminary trials, accordingly, of another kind, he connected a glass globe full of air, with a syringe or pump, exactly identical in construction with one of the forms of the ordinary lift, or sucking pump, and found that by setting the piston in motion he could empty the globe of air. He proceeded to make a number of interesting experiments, which added largely to men's knowledge of the properties of air, and have made his name and the city of his residence famous in every quarter of the civilized world. So many were the visitors that crowded to Guericke's house to witness his marvellous performances, that he had a large pump erected in his cellar, with tubes ascending into an upper room, and connected with suitable apparatus. At great receptions, the pump was driven all day by two men who kept emptying a very large copper globe of air. When an experiment was to be made, a communication was opened between this globe and the interior of much smaller vessels, the air contained in which was immediately greatly rarefied, and their cavities left nearly vacuous. Were this the proper place, we should have much to say in praise of Otto von Guericke.

The fame of the Magdeburg experiments soon reached England, and interested no one there so much as Boyle. He had been meditating, like Guericke, on Torricelli's results, and was considering how best a vacuum might be produced on the large scale, when he learned that he had

been anticipated. He would probably have succeeded in his schemes, and the likelihood of this, along with the certainty that Boyle had endeavoured to construct an air-pump before 1659, has led the late Professor Robison, the writer of the able article in the *Encyclopædia Britannica*, on Pneumatics, to claim for Boyle the merit of being an independent, though not the first, inventor of the air-pump. 'Boyle,' he says, 'invented his air-pump, and was not indebted for it to Schottus's account of Otto von Guericke's, published in the *Mechanica Hydraulo-Pneumatica* of Schottus, in 1657, as he asserts, *Technica Curiosa*.'[1] This is complimenting Boyle at Guericke's expense, in an uncalled-for way. The former, who was eminently free from envy, meanness, or jealousy, explicitly declares in a letter to his nephew, Lord Dungarvan, of date 1659, that he did not set about the construction of an air-pump till he had heard of Guericke's 'way of emptying glass vessels, by sucking out the air at the mouth of the vessel.' Encouraged by the report of Guericke's success, Boyle called in the assistance of Greatorex, or Gratorix, a well-known instrument-maker of the time, frequently referred to in Pepys' Diary. Between them, however, they could not succeed in fashioning a serviceable machine, and Boyle had recourse to Robert Hooke, then a youth of some three-and-twenty, but already remarkable for his mechanical genius. No drawing of Greatorex's contrivance has been preserved, but Hooke, who had seen it, says of it, in his cutting way, that it 'was too gross to perform any great matter.'

At this point, the history of the air-pump in England begins. Statements, the most erroneous and contradictory, occur in the works of writers of the highest authority, nor do we know any treatise which gives an accurate account

[1] *Encyclopædia Britannica*, 7th edition, Art. Pneumatics, p. 72.

of the steps in the invention and improvement of the machine, or which rightly marks the parties by whom they were made.

Men so eminent as Dr. Thomas Young and Professor Baden Powell, have misled authorities of less esteem in this matter. Professor Robison, in addition to other mistakes, in his 'Treatise on Pneumatics,'[1] attributes one most important improvement (the double barrel), in one place to Hooke, and in another place to Hauksbee. Mr. Weld has completed the confusion, by announcing in his history, that the Royal Society has in its possession an ancient air-pump, once the property of Boyle, which is totally unlike any instrument figured or described in his works. It is time to set this matter to rights, and it may be well to remind the reader that, although the air-pump was invented in Germany, nearly all its great improvements have been made in England.

Greatorex's contrivance having been thrown aside, Hooke constructed for Boyle, in 1658 or 1659, the air-pump with which his first series of pneumatic researches was made. The merit of devising this instrument should seem to be almost entirely Hooke's. Boyle at least claims very little to himself. His account of his first air-pump is contained in his treatise, entitled, 'New Experiments, Physico-Mechanical, touching the spring of the Air and its effects, made, for the most part, in a new Pneumatical Engine; written by way of Letter to the Right Honourable Charles, Lord Viscount of Dungarvan, eldest son to the Earl of Corke.' The date of the letter is 1659. It is reprinted in Birch's Boyle, vol. i. Boyle mentions that he put both Mr. G. (Greatorex) and R. Hooke to contrive an air-pump, which should be more manageable than the German one,

[1] *Encyclopædia Britannica*, Art. Pneumatics.

and free from its defects; and then adds, 'After an unsuccessful trial or two, of ways proposed by others, the last named person (R. Hooke) fitted me with a pump, anon to be described.'[1] In a manuscript which was not published till after his death, Hooke himself says, 'In 1658 or 9 I contrived and perfected the air-pump for Mr. Boyle.'[2]

This instrument consisted 'of two principal parts, a glass vessel, and a pump to draw the air out of it.' The pump was so placed on a wooden tripod, as to have its mouth downwards, so that the piston-rod, or shank of the sucker, when, like the ramrod of a musket, it was pushed home, ascended into the cylinder or barrel. The object of this inversion was to allow the glass vessel, from which it emptied the air, to be placed in a vèrtical position above the pump. This glass vessel Boyle called the receiver, an apparently paradoxical title for a hollow globe, which was, if possible, to be emptied of its original contents, atmospheric air. The name, however, which is still retained, though modern air-pump receivers are differently constructed, was eminently significant, and marked an important difference between Boyle's air-pump and Otto von Guericke's.

The receiver was a globe, or rather pear-shaped vessel, with a large aperture at its wider upper end, provided with an air-tight, moveable cover. Through this aperture the vessel could be made to *receive* any object, such as a burning candle, or a living animal, on which it was intended to try the effects of a vacuum. The hollow stalk of the pear-shaped receiver terminated in a brass tube, provided with a stop-cock, and ground to fit into the upper end of the inverted cylinder. The latter had an opening in it close to the place where the stop-cock entered, which could be

[1] Birch's Boyle, vol. i. p. 7. [2] Waller's *Life of Hooke*, p. 3.

closed or opened by a brass plug, ground to fit it, and managed by the hand of the experimenter, or the worker of the pump. The piston, which had no aperture or valve in it, was not moved directly by the hand. The piston-rod had teeth cut on it at one side, so as to form a rack, which was raised or depressed by a handle acting on a pinion or toothed wheel, working into the teeth of the rack, as in the air-pumps of the present day. We shall not dwell more minutely on the peculiarities of the original English air-pump. An engraving of it will be found at the end of the first volume of Birch's Boyle, and in the second volume of Shaw's Boyle, p. 472. It was necessary to describe it somewhat minutely, for a reason which will presently appear. The most important points to be noticed about it are, that unlike any later air-pump, the cylinder and the receiver were directly connected, and, further, that it was provided with only one barrel or pump. It appears to have been partly in reference to the former of those peculiarities, but also because he did not pretend to be able to produce an absolute vacuum, that Boyle named his instrument. He seldom calls it an air-pump. Once he speaks of Guericke's instrument as 'the wind-pump, as somebody not improperly calls it.' 'Pneumatic pump' also but rarely occurs. The title he preferred for his instrument was that of 'pneumatical engine.' Others called it the 'rarefying engine,' and it was known over Europe as *Machina Boyleana*,—Boyle's machine.

It was strictly a pneumatical, not a rarefying engine. It could be used to condense air into the globular receiver, as well as to withdraw air from it, as Boyle showed, and was thus something else than a mere vacuum-producer. Vapours and gases could also be introduced into the globe, as they were, in many of the experiments made with

it. It was thus best denominated an air or pneumatical engine.

At the present day, it would be considered an awkwardly contrived, ill-proportioned, and imperfect instrument. It taught Boyle, however, and his contemporaries so much, achieved such wonders, was so difficult of construction, and so costly, that its possessor called it his 'Great' Pneumatical Engine. He did not retain it long in his possession. With a rare and noble liberality, he presented it to the Royal Society in 1662, so that his poorer scientific brethren, who could not afford so expensive a piece of apparatus, might study pneumatics at his cost, and multiply experiments by means of the great engine. Acts as liberal have been done by many men on their death-beds, but seldom during their life-time; and wealthy philosophers have rarely descended from the height of advantage their riches gave them, to put into poor men's hands the means of rivalling and outstripping them in their favourite pursuits.

For six or seven years Boyle turned aside from Pneumatic research altogether, and no one took his place, at least in Great Britain. Finding that few new experiments had been made in the course of many years, he resumed his inquiries into the properties of the air, and began by constructing a new air-pump. His account of this, which he distinguishes as his 'Second Engine,' and of the experiments which he made with it, was published in the shape of a letter to his nephew, Lord Dungarvan, entitled 'A Continuation of New Experiments, Physico-Mechanical, touching the Spring and weight of the air, etc. etc. Oxford, 1669.' The letter is dated March 24, 1667, which we may consider the year in which the second English air-pump was constructed, though it may have been finished

in the preceding year. Various considerations 'invited me,' says Boyle, 'to make some alterations in the structure, some of them suggested by others (especially the ingenious Mr. Hooke), and some that I added myself, as finding that without them I could not do my work.'

The second pneumatical engine, like the first, had a single barrel, but the mouth of the latter, from which the piston-rod projected, was turned upwards, and the barrel stood in a wooden box, or trough, filled with water, which rose above the mouth of the cylinder, so that the latter was entirely under water. The object of this arrangement was to keep the leather of the piston, or sucker, always wet, and, as a consequence, 'turgid and plump,' so that it should move air-tight in the barrel. The piston, which was moved by a rack and pinion, had an aperture in it, which was closed and opened alternately, by thrusting in and pulling out a long stick, managed by the hand of the operator. But the great peculiarity and improvement in the engine was, that the receiver was not directly attached to the barrel. A tube, provided with a stop-cock, passed from the upper part of the side of the barrel in a horizontal direction along a groove, in a wooden board, covered by a thick iron plate, and was then bent up so as barely to project through the iron. The receiver was no longer a globe, or pear-shaped vessel, with various leaky apertures in it, but a bell-shaped, hollow glass jar, which, turned with its mouth downwards, like an inverted drinking-glass, was, to use Boyle's homely but expressive words, 'whelmed on upon the plate, well covered with cement.' When the pump was wrought, the air in the bell-jar, or receiver, was drawn out through the horizontal tube. The reader familiar with pneumatics will recognise in the whole arrangement a device which has been followed, with trifling alterations, in every later air-pump,

down to the present day. Every modern air-pump has its 'plate,' made however not of iron, but of brass or of plate glass ; and the bell-jar receivers are whelmed on upon the air-pump plate, as they were in Boyle's day. One great advantage of this arrangement was the increased stability given to the apparatus, by transferring the heavy glass receiver, which in the first air-pump was fixed by a narrow tube to the barrel, to a flat support, on which it rested on a broad base. Another advantage was the avoidance of many apertures, which could not be kept air-tight, so that air should not leak into the receiver. For it must be remembered, that every pneumatic receiver, or other exhausted vessel, lies at or near the bottom of a deep sea of air, as a diving-bell does at the bottom of a sea of water, and the latter does not more readily rush into the bell, through the smallest fissure, than air forces its way along the most imperceptible channel into the exhausted receiver. In the diving-bell there is air, at least, to resist the intrusion of water ; but in the receiver there is a vacuum soliciting the entrance of air. The fewer, therefore, the valves and stopcocks, the greater the chance of producing and preserving a good vacuum. A third advantage, to mention no more, was the facility which the plate afforded for placing on it any object, such as a candle, a barometer, a thermometer, a piece of clockwork, a growing plant, or the like ; and when the object was exactly arranged, bell-jars of various dimensions and shapes could be laid over it, and the pump set working. In the first pneumatical engine, bodies intended to be subjected to a vacuum were awkwardly inserted by a large aperture at the top of the receiver, or suspended within it by strings.

Boyle published the account of the experiments he made with his second air-pump in 1669, and laid pneumatics again almost entirely aside for seven or eight years. In 1676,

however, he began to think of resuming the subject, and he was fixed in his resolution by a visit paid him by a very ingenious and inventive Frenchman, *Denis Papin*, whose name is still connected with one of his many devices, the *Bone-Digester*, a peculiar high pressure steam-boiler, with which he effected strange triumphs in cookery. He has a place, and a high one, long overlooked, among the inventors of the steam-engine; and it will presently appear that he has a claim, also overlooked, to a high place among the inventors of the air-pump. Papin came to England in search of some situation which might afford scope for his mechanical genius. Boyle had lost the services of Hooke, whom, as we learn from Mr. Weld, he generously released from his engagements with him in 1662,[1] in order that he might become curator and experimenter to the Royal Society. Papin for a time became assistant to Boyle, whose indifferent health prevented him from experimenting much himself, and a new series of pneumatic researches was undertaken. This was the more readily accomplished, that Papin had brought with him 'a pneumatic pump of his own, made by himself,' and much superior in efficacy to either of Boyle's pneumatical engines.

An engraving and minute description of Papin's air-pump are given in Boyle's tract, entitled, 'A Continuation of New Experiments, Physico-Mechanical, touching the spring and weight of the Air, and their Effects, *Second Part.*' The substance of this tract was first noted down in French, by Papin, who performed most of the experiments; then translated by Boyle, or under his superintendence, into Latin, in which the treatise was first published. Afterwards, this was translated, under Boyle's supervision, into English, in which it is reprinted in Birch's Boyle, vol. iv. p. 504.

[1] Weld, vol. i. p. 197.

We cannot give the original date of the Latin or English editions of the tract, which must be regarded as the joint production of Boyle and Papin, but the experiments recorded in it are all dated. The first bears date July 11, 1676;[1] the last, February 17, 1679.[2] Papin's air-pump, which he brought with him, is, therefore, at least as old as 1676, which may be considered the date of its introduction into England. Its great peculiarity, as contrasted with former air-pumps, was, that it had two barrels. It was, according to Boyle, Papin's own contrivance. The former, referring to the use he made of the latter's mechanical devices in prosecuting his researches, says, 'Not a few of the mechanical instruments (especially the double pump and wind-gun), which sometimes were of necessary use to us in our work, are to be referred to his invention, who also made some of them, at least in part, with his own hands.'[3]

Papin's air-pump was a curious machine; it had two pumps standing side by side, the mouths of the barrels being turned upwards. Each of the piston-rods terminated in a stirrup attached to its upper end, and the stirrups were connected by a rope or cord, which passed over a vertical grooved wheel or large pulley fixed on a moveable axis. To work the machine, the exerciser of the pumps, as he is called in the original account, put his feet into the stirrups, and holding on, as it should seem, by his hands, to the upper part of the frame-work of the pump, or leaning against it (for the description is not precise on this particular), moved his feet alternately up and down as a hand-loom weaver does, or a culprit on the treadmill. The pistons or suckers, which were bottomless brass cylinders, had valves opening upwards, like that of an ordinary water-

[1] Birch's Boyle, vol. iv. p. 519. [2] *Ibid.* p. 593. [3] *Ibid.* p. 506.

pump; and similar valves were placed at the bottom of the cylinders, which were filled with water to a certain height, that the pistons might move air-tight in them. From the cylinders, tubes passed to a common canal, terminating in the air-pump plate, on which receivers to be exhausted were laid, as in Boyle's second engine.

The advantages of Papin's arrangement were very great. When a single pump is used, it becomes increasingly difficult, as the exhaustion proceeds, to draw out the piston against the pressure of the external air, which comes towards the end to oppose an unresisted force equal to nearly fifteen pounds on each square inch, to the extrusion of the piston. When the piston, on the other hand, is pushed home, it is driven into the barrel, with the same force which resists its withdrawal, and is liable to break the valves, or injure the bottom of the cylinder. But if the piston-rods of adjoining cylinders are balanced against each other, as those in Papin's machine were, so that the one ascends as the other descends, the evils described are all obviated. The resistance which the air offers to the ascent of the one piston is balanced, or nearly so, by the force with which it compels the other piston to descend, so that the two hang against each other almost in equilibrio. A very slight expenditure of force, accordingly, little more than is requisite to overcome the friction of the moving parts, suffices for the working of the pump. A double-barrelled air-pump not only exhausts twice as expeditiously as a single-barrelled one, but does double work for nearly the same expenditure of force. In this respect there is an essential difference between a double-barrelled air-pump and a double-barrelled gun. In the latter, a double effect is gained only at the expense of a double expenditure of time and force. Two gun-barrels require twice the charge,

loading, ramming, priming, and firing of one barrel, and twice the time to load. In the air-pump, on the other hand, the working of the one piston renders much more easy the work of the other, and diminishes the time requisite for working both. The barrels of a musket are isolated, though lying side by side, and are not mutually dependent; but the pistons of the air-pump are, as it were, organically connected, like twins, and aid each other's movements. The peculiarity of Papin's device would have been more apparent, if his machine had been called, not the double-barrelled, but the twin-piston air-pump. The twin-pistons were not the only advantage of Papin's pump; its valves were opened and shut by the air which passed through the apertures they covered, so that the valves were self-acting, like those of a water-pump. If the pistons were only kept alternately ascending and descending, nothing else was needed for the working of the machine. In Boyle's pneumatical engines, on the other hand, in addition to the labour of working the pump, the operator had, at every stroke of the piston, to shut a stop-cock and thrust in a plug, or to open a stop-cock and pull out a plug. His engines, therefore, could not be wrought swiftly.

It is not a little singular, that Papin's air-pump should have been overlooked by most later inventors and writers, at least in England. We have not found it referred to in any recent work of authority, although its curious stirrup-arrangement, which has been employed in no English air-pump, might have been expected to attract attention towards it. Papin is mentioned by Nairne incidentally, as an improver of the air-pump.[1] Dr. Hutton, in his *Mathematical Dictionary* (1796, vol. i. p. 55), mentions Papin's two barrels and twin-pistons, but not the stirrup-arrangement.

[1] *Phil. Trans.* 1777, p. 635.

In Shaw's Boyle the whole machine is described and figured, but Papin's name is not once mentioned,—an omission which, at the present day, would be considered inexcusable in an editor or abridger. The double pump must pass, with Shaw's readers, for an invention of Boyle's, yet even the latter's great name has not kept the double-barrelled stirrup air-pump in remembrance—a significant proof how little Boyle's works, even when abridged, are read by the very historians of his labours.

It is in connexion with the double-barrelled air-pump that the accepted history of the instrument is chiefly erroneous, but the mistakes made in reference to the more complex engine, have ultimately involved in confusion even the authentic records of the steps by which the earlier single-barrelled pump was improved. Recent writers on pneumatics, having overlooked Papin's machine, whilst they universally acknowledge the importance of two barrels with the pistons counterbalancing each other, have attributed this great improvement to Boyle, to Hooke, or to Hauksbee, an admirable observer and very ingenious mechanician, who flourished in the first decade of the eighteenth century. Professor Baden Powell, in his interesting *History of Natural Philosophy* (p. 235), says, 'Boyle made the first improvement, and reduced the air-pump to nearly its present construction.' So general a statement, in a brief popular treatise, would not in itself, perhaps, call for criticism. It is quoted, however, by Mr. Weld, and has contributed, along with other things, to mislead him into a curious error, which, if uncontradicted, will propagate a grave mistake. The point of Professor Powell's statement lies in the word 'nearly.' In our judgment, he uses it with much too great a latitude. Boyle's two pneumatical engines were awkward in construction, and without self-

acting or mechanical valves. They could not be wrought swiftly, and they produced only an imperfect vacuum. Boyle himself ingenuously and ungrudgingly acknowledges, that Guericke's pumps exhausted better than his. In compliment to his beautiful Pneumatic Researches, the whole of Europe, designedly passing by the prior claims of the Burgomaster of Magdeburg, called the air-pump vacuum '*Vacuum Boylianum.*' Boyle accepted the name, not as a compliment, but as a designation of what he intended when he used the word *vacuum* in his treatises. It referred to something between an absolute plenum and an absolute vacuum. It approached to the latter, but fell short of it. It was not Nature's vacuum, the thing she so much abhorred, but Boyle's vacuum, the best that the Honourable Robert Boyle could produce with his pneumatical engines. It seems well to notice, although it is a digression, lest we should be thought to have forgotten our duty as biographers, that those things are not pointed out to disparage the genius of the great philosopher. Professor Powell's statement lessens instead of exalting Boyle's claims to our admiration. His merit lies not in having constructed a perfect air-pump, but in having made an excellent use of a very imperfect one. There is a well-known class of painters who are always wandering about in search of 'a good light,' whilst Wilkies are completing great pictures in dim garrets. There is an equally well-known class of natural philosophers, for ever roving from mechanician to mechanician in search of better instruments; while others are discovering new planets, new living beings, or new elements, by apparatus which their dissatisfied brethren can demonstrate to be unfit for the purpose. Boyle did not belong to this tribe. He spared no cost, or time, or trouble, in endeavouring to obtain a good air-pump, but he did not aim

at an ideal perfection. With what he was aware was an imperfect instrument, he fell to work and achieved wonders. His clear, keen, cautious spirit supplemented all defects in mere machinery. Had he possessed, in 1659, one of the exquisite Parisian air-pumps of the present day, his discoveries would nevertheless have been for the time remarkable performances. Effected, as they were, with his awkward pneumatical engines, his pneumatic researches are evidences of a rare genius for experimental inquiry.

We may, therefore, without scruple affirm, for it is the truth, that Boyle's valveless, single-barrelled, leaky engines, with their slow-moving stopcocks and plugs, and ineffectual caulkings with sticking-plaster, were very differently constructed from the double-barrelled air-pumps of the seventeenth century, and were still more unlike the air-pumps of the eighteenth and nineteenth centuries. The difference, in the last case, is not quite so great, but nearly equals that between a Watt and a Newcomen steam-engine.

The particular claim, then, set up for Boyle, that he devised the double air-pump, implied in the general claim that he reduced the instrument nearly to its present construction, may be set aside without further notice. That merit is disclaimed by himself, and ascribed by him to Papin. Hooke and Hauksbee are claimants against Papin, not against Boyle. Professor Robison ascribes the invention of the double pump apparently to both of the former, yet, after all, decidedly to neither. In one place he states that Boyle 'was now assisted by Dr. Hooke.' 'This person made a great improvement on the air-pump by applying two syringes,' etc.[1] Professor Robison then goes on to describe an instrument identical with Papin's in the arrangement of its valves, and constructed on similar prin-

[1] *Encyc. Brit.* 7th edition, Art. Pneumatics, p. 80.

ciples. Instead, however, of the stirrups, connected by a cord passing over a pulley, the pistons are raised and depressed by a pinion or cogged wheel, working into racks cut on the piston-rods, as the single piston was moved in Boyle's pneumatical engines. No date is assigned to this alleged invention of Hooke's, nor does its describer quote or name any work in justification of his statement. Professor Robison then describes Hauksbee's pump, which is almost identical with the instrument attributed to Hooke, except that it is provided with the former's well-known long gauge — an appendage which measures, but at the same time diminishes rather than increases the rarefying power of an air-pump. Throughout the remainder of his treatise, Robison refers to Hooke and Hauksbee as if they had been independent inventors of the double pump, the priority, however, being given to Hooke; yet, in concluding his historical sketch, the latter's name is omitted, and the author, as if he preferred Hauksbee's claim, says, 'the double barrel and gauge by Hauksbee were capital improvements, and on principle.'[1]

Dr. Thomas Young, generally so exact, is not more accurate than Professor Robison. 'In the year 1658,' says the former, 'Hooke finished an air-pump for Boyle, in whose laboratory he was an assistant. . . . Hooke's air-pump had two barrels.'[2] Dr. Young—a rare thing with him—gives no authority for his statement; and he evidently supposes that the first English air-pump of 1658 was a double-barrelled one. We have already, however, pointed out sufficiently fully that 1658 or 1659 is the date of Boyle's great pneumatical engine which Hooke constructed for him,—a single-barrelled pump, with a globular receiver directly attached to it.

[1] *Op. cit.* p. 93. [2] Young's *Natural Philosophy*, edited by Kelland, p. 278.

Erroneous as Dr. Young's statement certainly is, it apparently derives the fullest confirmation from the announcement made by Mr. Weld in his *History of the Royal Society*, that that body possesses a double-barrelled air-pump presented to it by Boyle in 1662.[1] This instrument is shown to visitors, and can be seen by our readers for themselves at Somerset House. Its barrels are about fourteen or fifteen inches long, and the piston-rods have racks working into an unusually large-toothed wheel or pinion moved by a handle. The whole instrument resembles an air-pump of the present day.

It should seem at first sight impossible to question evidence so demonstrative of the true date of the double pump, as that supplied by the existence in the Royal Society's collections, of an air-pump presented to it by Boyle, and preserved since 1662 in its museum. Mr. Weld's statement, however, will not bear examination. He has himself, without intending it, supplied one of the means of disproving its accuracy. In the first volume of his *History* (p. 96), he quotes the following passage from the Journal Books of the Royal Society: 'January 2, 1660 (o.s.) The Society again met, when Lord Brouncker was desired to prosecute the experiments of the Recoyling of Gunns, and to bring it in against the next meeting, *and Mr. Boyle his Cylinder.*'

In explanation of the last allusion, Mr. Weld furnishes a note: 'This refers to the air-pump, which, according to Professor Powell, he reduced to nearly its present construction. The reader will be interested to know that the original air-pump alluded to above, and constructed by Boyle, was presented to the Society by him in 1662, and still remains in their possession. *It consists of two barrels.*'

[1] Weld, vol. i. p. 97.

The text and the annotation plainly contradict each other. Had Mr. Weld considered, he would have seen that an instrument emphatically called a cylinder, because provided with one barrel, could not possibly be provided with two barrels. The air-pump the Royal Society now possesses is not, then, the one the Society requested Mr. Boyle to bring to its meetings in 1660. Neither is it the instrument which he formally presented to the Society in 1662; for he had not a double air-pump in his possession till 1676, when he made use of Papin's. Mr. Weld's date of 1662 can only apply to Boyle's pneumatical engine completed in 1659. We have direct evidence, however, of the most weighty kind, to show what the instrument really was which Boyle presented to the Royal Society. In his 'Continuation of New Experiments Physico-mechanical, touching the Spring and Weight of the Air; Oxford, 1669,' already referred to, as containing the description of his second pneumatical engine, the following passage occurs: 'Being obliged to make some journeys and removes, which allowed me no opportunity to prosecute the experiments, I had made no very great progress in my design before the convening of an illustrious assembly of Virtuosi, which has since made itself sufficiently known under the title of the Royal Society. And having then thought fit to make a present to persons so like to employ it well of the great engine I had till then made use of in the physico-mechanical experiments about the air,' etc.[1] This decides both what the instrument was, and the date of its being given to the Society. It was the first or great pneumatical engine of 1659, and was presented to the Virtuosi before their incorporation as the Royal Society, which took place on the 15th of July 1662.[2]

Further evidence is not required; but it seems well to

[1] Preface, 1, 2.

[2] Weld, vol. i. p. 121.

notice, since a claim is set up for Hooke as having made a double-barrelled pump in 1660, or before 1662, that we have what amounts to a disclaimer of this from him. Waller, in his *Life of Hooke*, after quoting a statement of the latter's, already given in reference to his share in constructing Boyle's first pump, adds: 'The draught of this air-pump, and all its parts, as it was after published by Mr. Boyle, I have now by me, designed by Mr. Hooke, and I have heard him say, he was then sent to London by Mr. Boyle to get the barrel [*not barrels*] and other parts for that engine, which could not be made at Oxford.'[1]

In a curious way also, we have the united testimony of Boyle and Hooke, as to the configuration and appearance of the great engine. During Boyle's lifetime, he employed a Mr. Faithorne to engrave his likeness. The portrait is drawn in an oval or medallion, with pieces of apparatus grouped around it. The latter were designed by Hooke, and one of the two most conspicuous instruments is the great pneumatical engine with a bird in its globular receiver. This drawing is copied as a vignette on the title-page of each volume of Birch's Boyle. Three letters from Hooke to Boyle, of date 1664, containing references to the portrait and its accompaniments, will be found in the Boyle Correspondence.[2]

From all that has been said it will appear that the double-barrelled air-pump shown to visitors at Somerset House, is as little Boyle's original air-pump, as the famous mace of the Royal Society is Cromwell's 'bauble.' The wreck of the great pneumatical engine may still lurk in some garret or cellar of Somerset House. If so, it will be readily recognised by a reference to the original drawing, and should at once be transferred to a place of safety and honour.

[1] *Life of Hooke*, p. iv.

[2] Birch's Boyle, vol. vi. pp. 487, 488, 501.

One of Otto von Guericke's air-pumps is preserved in the Royal Library at Berlin. All lovers of letters and science would attach a high value to Boyle's air-pump, should it be recovered. It would be precious as a personal relic of Boyle and Hooke, and as a memento of the many great men who handled it, and gazed on it, and learned from it to alter all their conceptions of the properties of the air. It would be a monument also, and visible symbol of great discoveries, and preserve on permanent record, not the model or effigy, perhaps inaccurate, of the original air-pump, but the great pneumatical engine itself, which represented for the time the ingenuity of some of the most ingenious men of the age. Such rejoicings, however, are premature. Although it is nobly represented by an unbroken succession of no degenerate descendants, there is too much reason to fear that the original air-pump, like the Dodo, has long been extinct.

An ominous announcement of Mr. Weld's makes this too probable. In a comment on the state of the Royal Society's museum or repository in 1767, he says, ' There appear to have been a great number of models of machines and curious instruments; and it is a matter of regret that these have not been preserved *intact*, as they would now form a collection of undoubted interest.'[1] From this statement, it is plain that we may fear the worst. The wood-work of the pneumatical engine has, in all probability, been devoured long ago by the ' great fire,' or by some lesser fire, and its brass cylinders and appendages have descended into the melting-pot, to emerge from it in more ignoble forms. None of the present curators or members of the Royal Society, nor their predecessors, for more probably than a century, are responsible for the disappearance of Boyle's air-pump, if in truth it is lost.

[1] *History of Royal Society*, vol. ii. p. 43.

Nor would it be fair, when all things are considered, to blame Boyle's contemporaries, or immediate successors, or to accuse them of indifference or neglect. The instrument was presented to them, not as a curiosity or relic, but as a machine to be freely used for the performance of experiments. As such it was employed by the early members of the Royal Society, till other and better air-pumps came into use, and were at their disposal. During Boyle's lifetime it would not be valued as a memento or relic, and when we consider through how many vicissitudes the Society has passed; how often it has had to shift its quarters; and how limited its means of accommodation were for a long period, we cannot much wonder if the pneumatical engine was forgotten at some of the Society's removals, or deliberately abandoned to its fate. We may at least, with great reasonableness, assume, that its fragile glass receiver had been broken to pieces, before the close of the seventeenth century. The strange inverted cylinder, and awkward wooden tripod, which would then remain, would not readily be recognised, even by instrument-makers, as the exhausting apparatus of an air-pump. Only one, or, at most, two engines like it, appear to have been constructed, and these did not long remain in use, so that very few, after the lapse of fifty years, would be familiar with the appearance of the great pneumatical engine. After Hooke's death, in the very beginning of last century, there was none living likely to take a special interest in its preservation. Some zealous curator, if it then existed, would sweep it into a corner, or sweep it away as lumber. Mr. Weld's original air-pump results from the combination of two quite unconnected facts—the one, that Boyle gave the Royal Society an air-pump in 1662; the other, that the Society now possesses an old air-pump. That the latter is not the original great

pneumatical engine does not admit of doubt. Boyle, moreover, is not known to have presented more than one air-pump to the Royal Society. Unless, therefore, there is evidence of the most explicit kind to show that the double-barrelled instrument was once the property of that philosopher, we must hold it as highly improbable that it ever was in his hands. It will presently appear that it probably does not belong to his age, but is an air-pump of the eighteenth century.

A few words will conclude the early history of the English air-pump. Papin's double pump does not appear to have been directly copied by English instrument-makers, so that its stirrup arrangement, in particular, was practically unknown. We have been unable to find any allusion by Hooke himself to his having constructed a double-barrelled air-pump, nor has any reference been given by those who affirm that he did, to any existing instrument, or drawing, or account of it. It would be dangerous, however, to assert an absolute negative on this point, for Hooke's papers are very numerous, are immethodically arranged, ill edited, and not easily consulted. Yet had there been any notorious declaration of Hooke's on the subject, it would have been quoted by those who favour his pretensions. On the other hand, Waller, who sets up a well-founded claim on Hooke's part to Boyle's air-pump, limits the claim to the one-barrelled pneumatical engine of 1659. Boyle and Hooke were, from first to last, attached friends, and in constant communication with each other. Had Hooke devised a new air-pump, Boyle was the first person to whom he would have shown it; and even if he had not explained its construction to Boyle, the latter could not have failed to become acquainted with it, through one or more of his large circle of friends and acquaintances.

Boyle, however, who acknowledges his obligations to Hooke's ingenuity in reference to the second as well as to the first-air-pump, speaks of Papin's double barrel as something quite new to him, and extols its advantages. If Hooke, therefore, constructed a double pump, it must have been of later date than Papin's, which he may have seen, for Papin and he must often have met at the Royal Society, and perhaps at Boyle's residence. At all events, through Boyle's account of the instrument, Hooke must have been familiar with Papin's pump. Hooke (*ob.* 1702) survived Boyle (*ob.* 1691) about ten years, and may have constructed a new air-pump after the latter's death, but we have not been able to find evidence that he did.

The first double-barrelled air-pump of English construction, of which, so far as we are aware, a figure and description are extant, is Hauksbee's. They occur in a small quarto, 'Physico-Mechanical Experiments on Various Subjects, by Francis Hauksbee, F.R.S.' In the preface, the author says, 'The Honourable, and most excellent Mr. Boyle . . . gave much light into the causes and operations of nature; and particularly by the invention of that most useful instrument, the air-pump. The principal subject of the following papers is, an account of great and further improvements of this noble machine, the air-pump, and of many new experiments made thereby.'

The date of Hauksbee's work is 1709, but it consists chiefly of reprints from the Philosophical Transactions of papers published in earlier years. All of these papers are of later date than 1703, after which we may date the pump also. It is not unimportant to notice, that it was not made public, and probably not constructed, till after Hooke's death. Hauksbee speaks of it as an improvement on Boyle's air-pump. Whether he is to be understood as re-

ferring to Papin's machine does not appear, but if familiar with Boyle's descriptions of air-pumps, he could not be ignorant of Papin's. At all events, Hauksbee's pump (the long gauge excepted) is simply Papin's, with the stirrup arrangement and pulley replaced by racks on the piston-rods, and a pinion, moved by a handle. The advantages which attend the employment of two barrels, with their pistons balanced against each other, so as to be nearly indifferent to the pressure of the atmosphere, are dwelt upon at great length, as if they had been realized in Hauksbee's instrument for the first time. All those advantages, however, are pointed out with as much distinctness in the description of Papin's instrument of 1676. In truth, the excellence of Hauksbee's pumps did not lie, as Professor Robison thought, in the introduction of any new principles (the long gauge excepted), but in the combination of recognised principles, and in the nicety of mechanical construction of the pumps. They were a happy union of the best peculiarities of Papin and Hooke's air-pumps. Hauksbee adopted the double-barrel, counterbalancing pistons, and self-acting valves of Papin, but replaced his awkward stirrups and pulley, by Hooke's rack and pinion. We are strongly inclined to believe that Hooke's supposed invention of the double pump has originated in the observation of his rack and pinion in most modern air-pumps. It should seem, however, according to the evidence hitherto produced, that Hauksbee, not Hooke himself, first applied the latter's device to the double air-pump. Nevertheless, Hooke is entitled to be named in connexion with his own contrivance, and thus he will have a threefold connexion with the instrument, as deviser of the first air-pump, as one of the devisers of the second, and as the author of the method of raising and depressing the pistons in the fourth. Yet it cannot be denied, that the great

merit of the early double pump, does not consist in the mode, whatever it be, employed to move the pistons, but in their mutual twin dependence, and in the arrangement of the self-acting valves. To Papin all this merit belongs. Whether he was the inventor of the instrument he showed to Boyle, we cannot positively affirm. Boyle understood that he was. Winkler, who was Professor of Natural Philosophy at Leipsic, in the middle of last century, in his *Elements of Natural Philosophy*, gives a good sketch of the history of the air-pump. Hauksbee, and Leupold of Leipsic, who was contemporary with Hauksbee, are the only parties to whom Winkler refers as having a claim to be considered inventors of the double air-pump. He makes no allusion to Papin's. M. Libes, in his *Hist. des Progrès de la Physique*, states, that Papin and Hauksbee are the only claimants of the double pumps; and that Cotes of Cambridge, a contemporary of Hauksbee, attributed the invention to Papin.[1]

The reader will now understand why we should think it in the highest degree improbable that the double-barrelled air-pump of the Royal Society ever belonged to Boyle. It is possibly a relic of Hooke's, and of the seventeenth century, but more probably a memento of Hauksbee, and belonging to the eighteenth century.

By such steps was the modern air-pump conducted through its first improvements. They were but four, and we briefly recapitulate them here, for the sake of such readers as wish only the fruits of an historical investigation.

1. 1659. The construction of a pneumatical engine, consisting of a single-barrelled pump, with a solid piston moved by a rack and pinion, and a globular glass receiver directly communicating with the cylinder.

[1] *Hist. des Progrès de la Physique*, iii. p. 56.

II. 1667. The separation of the glass receiver from the cylinder, and introduction of the air-pump plate, on which bell jars could be placed and used as receivers.

III. 1676. The introduction of the double-barrelled pump, with self-acting valves in the cylinders and pistons, and with piston rods suspended at opposite ends of a cord, passing over a pulley.

IV. 1704. The combination of the rack and pinion of the first and second air-pumps, with the two barrels, twin pistons, and self-acting valves of the third.

Great improvements have been made in air-pumps, even recently, although they do not generally differ much in external appearance from those constructed by Hauksbee in the beginning of last century. The perfection of an air-pump lies in certain nice mechanical adjustments of concealed valves, and other internal, and for the time invisible, arrangements, so that mere similarity or even identity of outward appearance is no criterion of equality in effective power. An ordinary observer could not, by a casual inspection, distinguish a chronometer which varies only a second in a week, from a chronometer which keeps time no better than a Dutch clock. We must guard against the notion that no improvements have been made since Boyle's day, because air-pumps look the same. Historians of past successes, we would avoid the error into which historians so easily fall, of exaggerating the past because it is the past. The catholic, generous Boyle, were he to revive among us, would gaze with wonder and delight at our glass-barrelled, glass-plated, exquisite air-pumps, and cease to call his own the Great Pneumatical Engine.

We have seen what Boyle's air-pump was. We have now briefly to see what he did with it. Here, no Hooke nor Papin can divide the merit with him. Boyle was not

eminently constructive, as they were, in the matter of mechanical devices, but he was very inventive in devising appropriate experiments, and he could always compass their execution. Hence it happened, that, though Otto von Guericke, a man of great genius, had the start of Boyle by some five years, the latter made so much better use than Guericke of the air-pump, that it was named, by admiring Europe, Boyle's, not Guericke's, machine.

There are few of the mechanical properties of the atmosphere which he did not learn for himself, and teach to others, by his instrument. Its vital or life-sustaining powers, he understood better than most even of the learned physicians and naturalists of his time. He made some progress in investigating the chemical relations of the air, and ingeniously converted his pneumatical engine, as occasion required, into a retort, an alembic, a still with its condenser, and a gas apparatus, in which he evolved and liquefied fumes and vapours, and eliminated gases by 'corrosion and fermentation.' Galileo, Torricelli, Pascal, Guericke, and others had shown that air is heavy, and that it exerts a great pressure on all bodies within it. Boyle multiplied and varied the proofs of this by endless impressive and convincing experiments. He made a tolerable approximation towards exactly determining this specific gravity of air, as compared both with water and mercury, and came nearer the true number than any of his early contemporaries.

The power of air to conduct sound had been long vaguely credited, then doubted, and finally, as it appeared, proved not to exist. Endeavours had been made to settle the question by very ingenious experiments with the Torricellian vacuum, in which a sounding body was placed, in the expectation that, when made to vibrate, no sound

would be heard. Allowance, however, was not made for the conducting power of the walls enclosing the vacuum, and the trial, in consequence, was conducted in such a way as to allow the sounding body to strike on the solid glass boundaries of the void, as the tongue or hammer of a bell strikes the bell. A sound, accordingly, loud and clear, was heard, and the conclusion was drawn that the presence of air is not essential to the conduction of sounds, even when those are produced, like the cries of birds flying high in the air, or a peal of thunder, in circumstances where they cannot be conveyed to the ear along solid conductors. Guericke repeated the trial with his air-pump, and found that sound was not transmitted through a vacuum. The experiment, however, taught him little. He does not appear to have expected the absence of air to annihilate sound. He seems to have thought, that if air conducted sounds, we should not hear these when much to the leeward of a sounding body. Guericke confounded the transference of sounds, by a series of waves or undulations, *through* the air, with its carrying or conveyance, like smoke, *by* the air. A mistake of the same kind is constantly made in reference to all the physical forces, such as light and heat, which are propagated by undulations or vibrations. A simple experiment and a familiar observation will correct the false conception, and show what misled Guericke. The experiment is to drop a stone into a still pool. A ring-like undulation immediately commences to travel from the place where the stone plunged into the water, and, increasing in diameter, spreads on every side, till it reaches the shores of the lake. But the outer wave which ripples on the shore is not the very water which the stone first disturbed. Each particle of water changes its place very little, and moves only through a small space, although the impulse commenced

by the stone travels over a wide area. A sounding body causes air to undulate, as the stone does the water.

The observation which may be considered equivalent to an experiment tried for us by nature, is the spectacle of a field of growing corn, shaken by a gentle wind. When we look at such a field, we see wave after wave sweep over the nodding grain from one side of the cultivated space to the opposite. The ears of corn, however, have not been swept from one corner of the field to the other. Each ear, anchored by its stalk to the soil, has only moved forward a little space in the direction of the wind, and then moved back to its original position. Sound travels through the atmosphere in the same way, not borne along with moving particles of the atmosphere, which fly like arrows, carrying the sound with them, but propagated as a vibration transferred from particle to particle of the air, which is thrown into undulations, but does not flow as a current. The effect of a sounding body on the atmosphere is like that produced when we strike the first of a long row of billiard-balls, so as to make it impinge on the second. An impulse runs along the line, moving each intermediate ball very little, but causing the last to fly off from the row. Another striking illustration of what we are seeking to explain, is supplied by the firing of a great gun. The flash of the cannon is rendered visible to the eye by a series of very swift undulations, which travel in every direction from the cannon as a centre. The sound, in like manner, by slower undulations through the atmosphere, reaches the ear, whilst the smoke does not radiate from the centre, but is carried by the air entirely to windward.

How far Boyle understood all this, we cannot precisely tell, but he was one whom no theory would prevent from subjecting to direct trial, what he thought experiment only

could decide. Undeterred by the results of the investigations of Guericke and others, he tried for the first time, in an unexceptionable way, whether sounds are inaudible in a vacuum. His *experimentum crucis* was as simple and elegant as it was decisive. He hung within the globular receiver of his great pneumatical engine, by a thin string, a watch with its case open. The receiver was large enough to contain sixty wine-pints of fluid, so that the watch, suspended in its centre, was far removed from the glass walls of the globe.

The sounding body was thus detached from all solid conductors, the thin string excepted, which was as slight a conductor as well could be used to support the watch. When all had been arranged, the air was slowly withdrawn from the receiver, and the beating of the time-piece, which was loudly audible at first, fell fainter and fainter upon the ear as the exhaustion proceeded, till at length it ceased to be audible at all, whilst the silent hands moved as before round the dial-plate, showing that the movements of the watch had not ceased, but only their sound. The air was then slowly readmitted, when the sound reappeared, waxed louder and louder, and finally reached its previous intensity, when the receiver was filled as at first with air.

The experiment was repeated by Boyle in various ways, and the ingenuity of later observers has supplied many contrivances for making the experiment demonstrative to large audiences, by whom the ticking of a time-piece could not be heard. The original trial, however, was complete. Since Boyle's time, no natural philosopher has doubted that the air is the great and essential medium of sound.

From the earliest times, the necessity of air to the maintenance of combustion must have been more or less distinctly perceived, yet the notions of the ancients on the sub-

ject were at the best very vague. Nor could Boyle do more than dissipate some of the vagueness; yet he did a great deal. With untiring patience, he enclosed in his engine lighted candles, portfires, loaded pistols, which he fired by dexterous contrivances, and many other arrangements of combustible bodies, which he rapidly cut off from a supply of air, or did not kindle, as in the case of gunpowder, till the air was withdrawn. He did not interpret, or he misinterpreted much that he saw was instructive enough; but he understood a great deal of what he witnessed. He could not only infallibly demonstrate that without air, flame could not exist, but he dimly foresaw what, apparently, might be easily apprehended, and yet was not clearly perceived till a century later, that a burning body is not parting with some fiery essence or principle to the air, the loss of which renders it incombustible, but is robbing the air of part of its substance, which is added to the burning mass, and makes it insusceptible of combustion. If a flaming candle owed its luminousness simply to its giving off an inflammable principle, it should flame brightest in a vacuum, which would solicit the evolution of the principle of heat and light, whereas a candle will not flame at all in a void, but disappears, as if snuffed out by invisible snuffers. The moon has no atmosphere, and, therefore, we may be certain no tallow-chandlers, no camphine lamps, or coal gas companies. No lunar Diogenes goes about seeking for an honest man, at least with a lantern. The only torch that would suit a Cynic in the moon, is the electric light, which feeds upon electricity, and not upon air.

Imperfect as Boyle's views on combustion were, they greatly exceeded, in clearness, those of his immediate successors. It was by defect and omission that he erred, as well as Mayow and Hooke, who also, for their time, had

unusually accurate notions of the nature of combustion, rather than by holding positively erroneous opinions. After those clear thinkers came the Dark Middle Age of modern chemistry, with its chimera of a 'phlogiston,' or invisible, unsubstantial fire-essence, in theory an entity and yet a non-entity; in fact, a veritable dark lantern, which Lavoisier at last succeeded in knocking to pieces, after satisfying every reasonable person that there never had been, at any time, a light within the lantern to make it worth preserving. A hundred years of retrograde speculation on combustion, divide Boyle's clear views on the subject from the clearer but still defective views of Cavendish, Watt, Priestley, and Scheele, which culminated in Lavoisier's clearest announcement of the theory of burning, in which, nevertheless, as in the sun, the telescope of a more modern chemistry can see dark spaces.

Respiration and combustion are closely analogous as chemical phenomena. The first man that quickened a smouldering brand by blowing upon it, had discovered that the breath of life is also the nourisher of flame. The eastern moralist compared life to a vapour. The quenched, inverted torch, was a classical emblem of death, and the modern poet sings of the 'Vital spark of heavenly flame.' Boyle was one of the first to give such expressions a literal signification, and to announce, with no little clearness, the aphorism of modern chemistry, that no gas or gaseous mixture, in which a candle goes out, will support animal life. As he, like all the chemists of his century, confounded the various gases under a common name of air, it was impossible that he should announce the aphorism in the terms we now do, but he substantially gave expression to it. No subject interested him more than the relation of life to air. He tried a great number of experiments, many

of them, it must be confessed, very cruel, as to the influence of a vacuum on living animals.

It was with no wanton cruelty, still less in the spirit of philosophic indifference, that Boyle tortured animals. Burnet tells us that his sensitiveness to their sufferings made him abandon the study of anatomy, in that age prosecuted with a needless amount of infliction of pain on living creatures. We can well believe this, for it was quite in keeping with the amiability and benevolence of Boyle's character; but no indications of his humanity appear in the records of his pneumatic researches. Experiments which would shock our readers if but alluded to, and which involved inconceivable and protracted agony to their subjects, are as calmly related as if they had been performed upon a candle or a time-piece. This would not seem wonderful in a strictly scientific narration, which supposed pain taken for granted, and left it unnoticed. But it was not Boyle's way to progress though a subject, like a railway train implicitly guided by the rails, nor even like a stage-coach, keeping, on the whole, the middle of the road. He got over his ground as travellers ride across Salisbury Plain, by a kind of zig-zag progression, which can make the sharpest angles on either side without risk of breaking a fence, or striking a wall, or falling over a bridge. Yet not a whisper does he utter as to the cruelties he was perpetrating, although Hooke, who has the reputation of being an unamiable man, when describing an experiment on a living animal, cannot forbear giving vent to remorseful expressions as to the pain which the experiment cost himself as performer and spectator, nor omit recording that he will never repeat so cruel a deed. The explanation of the anomaly is to be found in the intense conviction Boyle had, that his air-pump experiments would immensely improve physiology, enlarge men's know-

ledge of the nature of respiration, and put in the hands of the physician new methods of lessening human suffering.

The stream of Boyle's benevolence had scooped for itself one great channel, in which, fraught with gifts for his brethren, it all ran. He thought not of the agonies of a bird, when its pantings in the vacuum promised to teach him how to cheat consumption out of her victims. Nor should it be forgotten that Harvey's great discovery of the circulation of the blood had filled the disciples of Bacon with as extravagant expectations as to the results which should flow from the extension of his discovery, as men now-a-days anticipate from the triumphs of galvanism. The sacredness of even human life was forgotten. It is scarcely credible at the present day, that the chief physicians of London, contemporary with Boyle, applied to the presiding physician of Bedlam, for a lunatic, into whose veins they proposed to inject an animal's blood. When this extraordinary request was refused, they succeeded in persuading a crazy scholar, an *emeritus* out-pensioner of St. Luke's, though not on its roll, to submit to have sheep's blood transfused into his blood-vessels. Henry Oldenburg, the thrifty secretary of the Royal Society, may still be heard, in an existing letter in the Boyle Correspondence, chuckling over the crazy man risking life and what remained of reason for a guinea!

When men fared so, we cannot wonder that it went ill with pigeons and frogs. Boyle forgot everything but the mighty improvements in medicine which were likely to result from his experiments, and showed no mercy. And it is consolatory to think, that the transient sufferings of the innocent creatures he tortured, have served to lessen the agonies of generations of men, although the state of physiology in his day long prevented any harvest being reaped

from his trials. Till Priestley discovered oxygen, and Cavendish showed the chemical composition of air, and Lavoisier expounded the true relation of oxygen to combustion, respiration was an enigma, nor is it yet a perfectly solved problem. Boyle, however, had the faith of genius in the value of his early expositions of the relation of the atmosphere to life, and committed them contentedly, as a seed which should yet bear the choicest fruit, to the hands of his successors. His good taste was not so conspicuous as his faith. In the drawing of his second pneumatical engine he has introduced a revolting picture of a miserable cat struggling in the agonies of suffocation. In his medallion portrait as already noticed, he has a bird in the receiver of his air-pump. The most maligned of French Vivisectors would not venture on such drawings at the present day. Boyle was in many respects before his age; but noble Christian as he was, he was tinctured with its barbarity. The designs referred to, however, are important proofs of the value he set upon his experiments on animals.

We can say no more concerning his air-pump researches although much remains unnoticed; neither can we dwell upon the services he has rendered science indirectly, by the proofs he gave of the value of his machine as an instrument of research.

There is scarcely one of the physical sciences which is not indebted to the air-pump. Optics employs it to measure the refractive powers of gases. The science of heat has been indebted to it, in the hands of Leslie, Faraday, and others, for great strides of progression. Acoustics, by means of it, ascertains the laws which regulate the propagation of sound through elastic fluids. In many ways it is essential to the researches of the natural philosopher and physiologist, and it is an essential appendage of every chemist's

laboratory. It forms an essential part of the condensing steam-engine, and is employed on the largest scale in the purification of sugar, and in other economical processes. If it has failed in its most gigantic application, that, namely, of the atmospheric railway, Boyle, at least, is not to blame. Had the projectors of that scheme looked back two centuries, and read the philosopher's wailings over the failure even of the best sticking-plaster to close the chinks in his receiver, they would have thought twice before they tried to realize their project. When we think of all the air-pump has effected, we feel compelled to retract what we have said against Boyle's earliest and rudest instrument, and to unite with him in calling it the Great Pneumatical Engine.

Had our limits permitted, it would have been pleasant to dwell on Boyle's other achievements as a physical philosopher. We should have tried to show what an acute investigator of the laws of heat he was, often mistaken, always ingenious ; sometimes successful in bringing to light striking phenomena, and elucidating remarkable laws. He was the first to introduce into Great Britain the famous Florentine weather-glasses, which the short-lived but memorable Accademia del Cimento taught Europe how to make. England came thus to be provided with delicate thermometers earlier than countries lying nearer Italy ; and a great impetus towards the study of heat was communicated to the natural philosophers of our country. Boyle took a leading part in prosecuting the subject. He devised some very useful forms of the thermometer, and assisted in discovering a process by which the instrument might be infallibly graduated, so that all thermometers should agree in their indications—that is, should point to the same figure on their scale, when the heat affecting them was the same.

He did not, however, perfect a method of graduation. Hooke, Halley, and others, went further than he did, and Newton outstripped them all. The modern thermometer is as much his as the glass prism.

It would have been pleasant also to have shown how endless his distillations, cohobations, sublimations, and fermentations were, and what glimpses he got of great discoveries, which, nevertheless, he missed. He toiled unceasingly beside the huge furnace, which the Hermetic philosophers of his day thought essential to their work, and constructed of dimensions large enough to rival a limekiln, or serve a glasshouse, as may be learned from his letters and folios, by the smiling chemist of the present day, whose crucible-furnace would go into his hat, and his blowpipe into his waistcoat pocket. Boyle called himself the 'Sceptical Chymist,' but he had a weak side towards alchemy. He was constantly begging, borrowing, or purchasing medical recipes, and much of his time was wasted in the manufacture of specifics. Religious considerations probably precluded him from faith in the alchemist's long sought-for elixir of life, which should confer an earthly immortality on mankind. The elixir was the specific of specifics, which made lesser specifics needless; the cure for the one disease, Death, which swallows up all others. Boyle did not believe in such a specific, but there was nothing in Scripture to forbid the belief that the day might come when man's God-given skill should succeed in neutralizing disease, and Health should walk side by side with Life up to the very gates of the tomb. Boyle's furnaces, accordingly, were always at work, concocting elixirs of health, but their ineffectual fires blazed in vain. The dyspeptic, melancholic elixir-maker himself, was a poor specimen of the worth of his specifics, though this was perhaps as it should be. The alchemical

professors of transmutation never had by any chance a penny in their purses, and the hermetic process always began by the begging of so much base metal which the adept should transmute into silver or gold. Boyle was a stanch believer in transmutation, as he was well entitled to be, for there is no *à priori* objection to its possibility, as there is to the possibility of a self-sustaining perpetual motion, and in his time there appeared many proofs of transmutation having been effected. It may be realized any day. Boyle tried to multiply the precious metals, and the gold showed symptoms at least of coming. He amazed himself, and alarmed Newton, who counselled concealment, by an experiment where gold and mercury being mingled together grew very hot, and the latter seemed going to fix. There was nothing very alarming in the experiment, after all. It was only a costly way of illustrating, what a little gunpowder would have shown better, and a great deal more cheaply, that chemical combination is accompanied by the evolution of heat. Not long before his death, Boyle procured the repeal of a statute of Henry IV., which forbade 'the multiplying of gold and silver,' so that more successful transmuters than himself might engage in the fixation of mercury, without fear of their lives.

As a naturalist he was indefatigable. He observed for himself, collected specimens, read largely, and carried on an extensive correspondence with every quarter of the globe. Every one was pressed into his service, from the English ambassadors abroad, to the labourers in his gardens, and the sailors he fell in with. It was a transition-age, half credulous, half sceptical, but more the former than the latter, and many of Boyle's correspondents had eyes only for the wonderful. Among his unpublished works is a manuscript record of conversations with sea-captains and pilots. What

wonderful things sea-captains behold we know, and how ready they are to charm willing ears with them. Boyle was a very cautious, though inquisitive man, and had a great stock of common sense. He needed it all in estimating the value of the recitals made to him ; and we need neither wonder nor blame, if he sometimes stamped as authentic, narrations which, in reality, were half genuine mixtures of inaccurate observations, unintentional deceptions, and deliberate lies. He winnowed the wheat from the chaff, on the whole, very fairly, if we remember how imperfect his winnowing shovel was, and that there was but his solitary one at work. We may compare him, as a critic and methodizer of the Natural History of his time, to one of the Californian gold-washers of our own day. Up to his knees in water he stood, provided with one small wooden bowl, of his own making, with which to sift the gold from the sand. Down came the river, bringing grains of the true metal : brassy pyrites, particles which, to many eyes, looked more metallic than the gold ; yellow mica scales glistening brighter than the pyrites ; pebbles, gravel, shingles, clay, sand, and mud. With wonderful dexterity, everything considered, Boyle contrived to let nearly all but the gold flow on ; and if he occasionally mistook grains of the pyrites or mica for the noble metal, let it not be forgotten that his cautious temper made him err on the safe side, and think it better to save a little dross which could afterwards be purged out, than to permit any of the gold to escape.

What Boyle did in physics proper—in hydrostatics, for example, and in electricity—we must pass by. His discoveries in these would have won a reputation for a less versatile observer. We must notice him, however, as the self-appointed professor of an important art. We have called him already an Amateur Doctor. It would be fairer

to style him an Emeritus Physician. Padua or Leyden might have been proud of him, and gave the Doctor's hat to many less accomplished students of medicine. He knew anatomy well, and was often present at dissections. The meagre physiology of his time he had more than mastered, for his air-pump experiments on living animals threw new light on the great functions of respiration and the circulation of the blood. The properties of blood and bone, and of the other secretions and tissues of the body, he had made the subjects of repeated analyses. His knowledge of natural history made him familiar with the medicinal virtues of plants and minerals ; and his chemical skill, we have seen, was constantly exerted in preparing novel remedies. He amassed an immense collection of empirical recipes, and tried them on himself, on his friends, or, through the physicians he knew, on their patients. It is curious, indeed, to remark his eagerness on this point. Whatever else he and his immense host of correspondents write about, the majority of them have something to say about specifics. Now it is a request that 'the incomparable Mr. Boyle' will send them a little of 'Ens Veneris.' Then it is an announcement from a physician, that he finds '*Aqua Limacum*' (snail-water), or some other abomination, a powerful remedy. It was a certain way to Boyle's good graces to send him a new recipe, which he acknowledged by presenting the sender in return with one of his choicest formulæ, or a packet or phial of some catholicon, as insect or shell collectors exchange specimens. Every one assisted him. William Penn sent him Red Indian cures ; Locke gathered plants for him at the due season of the year. Boyle came in the end to be gratuitous consulting-physician and apothecary-general to a great section of England. Fellows of the Royal College of Physicians did not hesitate to submit cases

to him, and he was a prompt and bold practitioner. In 1665, Oxford gave him the honorary degree of Doctor of Physic.

Doctor Boyle's dispensatory was a catalogue of as vile abominations as ever sick man was compelled to swallow. The compilers of the Pharmacopœias of his time—for he was not a solitary transgressor—almost seem to have gone on the principle that the more loathsome the source of a remedy, the more potent was it likely to prove. Let invalids of the present day drink with composure their bitterest potions, and be thankful that they are not required, as their forefathers were, to turn cannibals, and masticate powdered human skulls, or the 'ashes of a toad burned alive in a new pot.' The nature of the subject forbids enlargement on what is an important chapter in the history of science, interesting to the moralist as well as to the physician, and full of humiliating proofs that we are all Clodios. 'What we fear of death' makes every other repulsive thing lose its loathsomeness and horror. Life is gladly purchased on the most hateful terms. If any reader thinks we exaggerate, let him turn to Boyle's 'Usefulness of Philosophy,' which he will find abridged in 'Shaw's Boyle,' vol. i. p. 94, and read the paragraph at the bottom of the page. If that does not satisfy him, he can read on. He will not read long, without exclaiming, with King Lear, 'An ounce of civet, good apothecary, to sweeten my imagination.'

In the occupations we have described, more than forty years wore away; but before we say anything further concerning Boyle's deeds, it will be well to resume his personal history, which we carried no further than the close of his minority. This may best be effected by going back, for a brief space, to the narrative of Philaretus. The reader who knows it only so far as we have yet abridged it, and who is

familiar with the wan, wasted, melancholy countenance, which looks out from the engraved frontispiece of Boyle's works, will find it difficult to connect that mournful face with the commentary on it, which his autobiography supplies. Yet the account is his own, and we have not selected passages which should show him to disadvantage. Those which we have taken, and others which are passed over, display him rather as an estimable, than an engaging youth. If he faithfully acknowledges his faults, he is no less careful to point out his virtues, and this with a minuteness and complacency not prepossessing.

There were better qualities, however, in Boyle, than those we have yet seen, and they are destined, as well as his weaknesses, to an early ripening. Whilst resident at Geneva, an event occurred, which, as we have already hinted, he was accustomed 'to mention as the considerablest of his whole life.' To prepare his readers for this occurrence, he tells us, in language quaint, but dignified, that up to the period of its happening, 'though his inclinations were ever virtuous, and his life free from scandal, and inoffensive, yet had the piety he was master of already so diverted him from aspiring unto more, that Christ, who long had lain asleep in his conscience (as he once did in the ship), must now, as then, be waked by a storm.' In the dead of night he was roused from his slumbers by the thunders of a fearful tempest. Waking with the alarm that always attends sudden starting from sleep, he gazed in terror at the unceasing flashes of lightning, till he 'began to imagine them the sallies of that fire that must consume the world.' The noise of the heavy rain, and the roaring of the winds, loud enough at times to drown the echo of the thunder, 'confirmed him in his apprehension of the day of judgment being at hand, whereupon the

consideration of his unpreparedness to welcome it, and the hideousness of being surprised by it in an unfit condition, made him resolve and vow, that if his fears were that night disappointed, all his further additions to his life should be more religiously employed.' Boyle does not conceal that 'his fear was (and he blushed it was so) the occasion of his resolution of amendment,' but he also tells us that 'the morning came, and a serener, cloudless sky returned, when he ratified his determination so solemnly that, from that day, he dated his conversion.' This happened when he was some fourteen years old. In after life, Boyle's religion was conspicuously free from the recognition of dread of punishment of crime, or the barter of good works for reward, as the grounds of Christian love and obedience. 'Piety,' he says, 'was to be embraced, not so much to gain heaven, as to serve God with.'

The piety which one grand natural spectacle awakened, another was first to shake to its foundations, and then to confirm. Soon after witnessing the thunder-storm, Boyle made some excursions through Dauphiny and the south of France. Whilst at Grenoble, 'his curiosity at last led him to those wild mountains, where the first and chiefest of the Carthusian abbeys does stand seated; where the Devil, taking advantage of that deep raving melancholy, so sad a place, his humour, and the strange stories and pictures he found there of Bruno, the father of that order, suggested such strange and hideous distracting doubts of some of the fundamentals of Christianity, that, though his looks did little betray his thoughts, nothing but the forbiddingness of self-despatch hindered his acting it. But after a tedious languishment of many months in this tedious perplexity, at last it pleased God, one day he had received the sacrament, to restore unto him the withdrawn sense of His favour.'

In the sketch of Boyle in the *Biographie Universelle*, of which Cuvier was one of the writers, allusion is made to the resemblance in cast of mind to Pascal, which Boyle's melancholy showed. It has been no such rare thing, however, among students of physics any more than among men of warm hearts and sensitive imaginations, that Boyle and Pascal should stand alone as displaying it. The 'Anatomy of Melancholy' has to do with all sorts of men, but chiefly with those possessed of very limited or very great intellectual gifts. Minds delicately poised are easily thrown off their equilibrium; like fine balances, which weigh to the almost incredible fraction of a grain, and as a consequence are deranged by the presence of a trace of dust in one scale, and would have a set to one side given them by the down of a moth's wing lying in one pan. Delicate balances, also, are easily strained if overloaded; and the same law in great measure regulates the mental weighing of all kinds of truth. Students of the physical sciences are often referred to, as if their studies had no tendency to ruffle the spirits or overtask the intellect. Cowper, in one of his letters, referring to the stir which the public ascent of a balloon had occasioned, contrasts his own sadness with the cheerfulness of the philosophers too much occupied and delighted with the outer world to brood much inwardly. Nor can it be questioned, that a relish for the natural sciences prevents that morbid introversion of spirit which metaphysical speculation, whether of an intellectual or emotional and æsthetical character, tends to encourage, where there is a natural tendency towards inward brooding. But it is the observation of the striking phenomena, not the study of the laws of physical science, that has the enlivening effect. Naturalists of the merely observing and describing class, and experimenters, fond only of showy phenomena and dexter-

ous manipulations, are a cheerful, gregarious race, delighted with a new specimen or a new machine, and happiest when imparting their pleasure to others. But when we rise to the great discoverers and lawgivers in physical science, we find a vein of melancholy as apt to show itself as in impassioned poets, or recluse metaphysicians, or mighty painters and musicians. All the great problems in natural science—as the nature of heat, of light, of electricity, of gravity—and still more all questions connected with life, bring us in the end, and by few steps, face to face with infinity and mystery. Weary nights and days are appointed to him who studies these things. Hope deferred makes the heart sick. Failure saddens and humiliates the spirit, unnerves the intellect, and embitters the temper. Ambition and vanity, pride and the love of power, are in the philosopher's nature as well as in the poet's, and deaden or pervert the love of truth. Brains can be crazed and hearts broken by other disappointments than those which unrequited love occasions; and in the chemist's laboratory, the astronomer's watch-tower, and the mechanician's workshop, despair has found many a victim. And where great genius is found unalloyed, or little debased by the meaner qualities of our common nature, and the love of truth burns as a pure light—the *lumen siccum* which Bacon desired in all philosophers, and which failure or disappointment cannot quench—the instinctive tendency of the highly-gifted spirit will be to include in its grasp more than even it can compass. The intellect then, though free from all emotional bias, may be crushed, as Samson was, by the very triumph of its own strength. We need not wonder, then, that a certain melancholy, easily deepened, is as consonant to the spirit of a Newton as a Shakspere, or that it requires but an apparently trifling matter to develop it in

either. Boyle's sadness was the fruit partly of his weakness, partly of his strength. He was only some seventeen when it first preyed on him; and the blame of producing it cannot be ascribed to physical science, in which as yet he was but a slender proficient. Neither, however, could physics cure it, for 'never after did these fleeting clouds cease now and then to darken the serenity of his quiet.' He plainly had a natural predisposition to gloom, which a weak body and a roving fancy favoured; and though his occupations up to his early residence in Geneva were not at all of a melancholy cast, they employed the mind too much, and the body too little, to keep the balance even between them. Boyle had unconsciously, and while yet a youth, adopted the maxim of the friend and chief counsellor of his later years, Archbishop Usher,—'it is better to wear out than to rust out.' The sword had already, and far too soon, begun to pierce the scabbard!

However much, nevertheless, bodily or mental idiosyncrasy, or both, may have predisposed Boyle to melancholy, yet something more, as he believed himself, was needed to give it the intensity and the direction which it assumed. He referred his despair, as we have seen, to Satanic temptation.

This is not a suitable place or occasion for discussing the Scripture doctrine of evil spirits, and their relation to man. But as biographers, we cannot avoid considering the effect which the belief in such a doctrine, as realized in his own experience, had upon Boyle. For the 'clouds returned after the rain,' and the temptation to disbelief and self-destruction returned at intervals during his whole lifetime, though never with the original severity. This fact supplies us with the key to much which we should in vain seek to unravel by searching through all his lengthened essays on heat and cold,

the 'Sceptical Chymist,' or the account of the Pneumatical Engine.

Whatever hypothesis he held as to the cause of his despondency, he could not but have been greatly affected, for the better or the worse, by so dark a temptation as that which haunted him. To see, like Macbeth, wherever he turned, a dagger thirsting for blood, 'the handle towards his hand,' was appalling enough; but it was worse still when the point turned as if magnetically toward his heart, and the blood for which it thirsted was his own. But when he further believed that this 'dagger of the mind' was thrust upon him by a fallen Angel, as malignant in purpose as mighty in power, to compel him to be the instrument of his own hopeless damnation, his belief, whether a wise or unwise one, could not but greatly embitter his agony. Yet whatever evil effect such a faith may be supposed to have had on some of the qualities of Boyle's nature, few acquainted with his life will doubt that it put far into the back ground, or blotted out altogether, many of his weaknesses. The remembrance and revisitings of temptations so fearful, could not but sober any mind, which retained its integrity in spite of their assaults. The applaudings of vanity spontaneously hush themselves, when the reins of self-control are trembling in the hand, and may be dropped from nerveless fingers at any moment, or flung away in despair. The praises of this world have no attraction for one who has lost his hold upon it, and has come against his will under the dominion of the 'powers of the world to come.' Although the 'poor ghost' had been dumb, and there had been no claim of filial obedience upon Hamlet, or purpose of revenge, we should still have heard him say as he turned from the spectral figure,

'Remember thee?
Yea, from the table of my memory
I'll wipe away all trivial fond records,
All saws of books, all forms and pressures past,
That youth and observation copied there.'

One glimpse of the world of spirits introduces a new perspective into that of flesh and blood, and changes the standard by which the value of earthly things is measured. If the dark visitant, however, stole away Boyle's cheerfulness, he took also with him his pride and vanity, and ennobled and dignified his character. How compatible even surrender to a despondency bordering at all times on despair is with the clearest good sense and sustained intellectual effort, Cowper's mournful history sufficiently shows. Boyle, moreover, did not surrender. He believed that he was fighting a great spiritual foe, but he was conscious also that he had prevailed. The mingled weakness and greatness of man which Pascal wondered at and mourned over, appear in nothing more than in such a battle. What can be more humiliating to a man, than to have his individuality (the only thing that really is his) intruded on against his will: the chamber of his secret thoughts, which he would not open to those he loves best, and could not if he would, made free to the most hateful of visitors; the very citadel of Mansoul with its gates flung back upon their hinges, and the daily haunt of evil spirits? There is no humiliation of man's natural pride greater than this. Yet surely there is no arena on which his God-given greatness is more manifest.

That, impotent to roll the gates shut again, he should still retain courage to fight against his terrible enemy, and face about and front him, is one of the strangest things in his Spiritual History. If in men's battles, the victory is considered great in proportion to the prowess of the vanquished,

the Christian militant raises the highest war-cry when he exclaims, 'We wrestle not with flesh and blood, but against principalities and powers.'

Boyle's life was thus pre-eminently what every man's life is, but especially every Christian's,—a battle and a fight. Melancholy had marked him for her own before his minority was ended, and he returned to England a grave man at twenty. To serve God and to serve man was now his deliberate and great aim. He did not nurse in secret, and increase by nursing, his sadness, or excuse himself, on the score of indifferent health, from the most laborious tasks. It is true that he kept constantly proclaiming himself a valetudinarian or an invalid, and selected the strangest places in his scientific papers for announcing to his readers that he had a distemper in his eyes, a threatening, or a fit of the stone, but all the while he was shaming the most healthy and vigorous of his contemporaries by the number and value of his labours. Time, which so many valetudinarians dawdle away, in unnecessary restings and slumbers, Boyle rigidly economized. Tradition reports that in his later days, when his residence in London, and the fame of his name exposed him to countless unprofitable intrusions, he used on occasion to hang out a board with the curt and peremptory announcement upon it, 'Mr. Boyle cannot be spoken with to-day.'

For a considerable period after his second return to England, Boyle resided chiefly at Stalbridge. In 1652, and again in 1653 he visited Ireland, and remained in it for a considerable period, chiefly engaged in business arrangements connected with the estates which his father had left him there. His time would have been spent but unpleasantly in that disturbed country, but for the attentions of Dr. (afterwards Sir William) Petty, celebrated as the founder

of the modern science of statistics. This accomplished man instructed Boyle in anatomy and physiology. In 1654, the latter returned to England, and took up his abode at Oxford, where, along with Dr. Wallis and others, he kept up the association of ingenious men which afterwards merged into the Royal Society. It was here also that the 'great pneumatical engine' was constructed, as already mentioned, in 1658 or 1659.

After the accession of Charles II. he removed to London and took up his residence with Lady Ranelagh. The king was very courteous to him, and Lord Clarendon urged him to enter into holy orders. Boyle, however, declined acceding to his request, partly because he thought that he could serve religion more if it was out of men's power to say of him as they said of the clergy, 'that it was their trade, and they were paid for it;' but especially, as Burnet tells us, because he had not 'felt within himself an inward motion to it by the Holy Ghost.' 'So solemnly,' adds the Bishop of Sarum, 'did he judge of sacred matters.' In 1665, he was nominated, by the express desire of Charles II., to the provostship of Eton College, then considered a post of great honour and profit; but as it could only be filled by one in orders, he declined it. In 1666, he was brought into great public notice in connexion with an Irish gentleman referred to by Dr. Birch, as 'the famous Mr. Valentine Greatraks, the Irish Stroker.' He produced marvellous cures by a process of manipulation closely resembling that practised by the animal magnetists of the present day. Greatraks was an honest and honourable man, and Boyle came forward to attest the reality of his cures. The celebrated astronomer Flamsteed, went to Ireland to be stroked by Greatraks, and was benefited either by the stroking, or a subsequent attack of sea-sickness, or, as he thought, perhaps by both.

In 1680, the Royal Society elected Boyle its president, but 'a great, and perhaps peculiar tenderness in point of oaths,' led him to scruple about coming under the obligations, which by its charter the president must incur, and he declined accepting an honour of which he was so worthy. He refused, indeed, every dignity that was offered him. Charles II., James II., and William III. enjoyed his society and frequently conversed with him, but he sought no favours from any of them. His brothers being all noblemen, he was several times offered a peerage, but he resolutely refused it, and his reputation has been all the more abiding. Even Lord Orrery, a man certainly worthy of remembrance, is not half so well known out of Great Britain as his untitled youngest brother. In modest seclusion he carried on his labours, nor did any very remarkable events occur to diversify the proverbially monotonous life of the philosopher and scholar, till, on the 23d of December 1691, he lost his sister, Lady Ranelagh, whom for nearly fifty years he had loved with that intense affection, which is often seen, after the effervescence of youth is past, to unite brothers to their elder sisters. Boyle had but imperfectly realized the greatness of his loss, when it was more than compensated. Before a week had passed, he was restored to his sister. He died on the 30th of December 1691, in the sixty-fifth year of his age.

His character as a natural philosopher may be gathered from what has been stated. He practically ignored all speculation on physics which was of earlier date than Bacon's publications. Aristotle he utterly distrusted, and Descartes he would not so much as read. To open his eyes on the outer world, and to read what it taught, with as unbiassed and unfettered a judgment as he could secure, was his great aim. He was a very cautious observer, and was

seldom misled when the whole facts came under his own notice, so that he was eye-witness as well as judge of the nature of the information which a phenomenon or experiment furnished. But he was often compelled to deal with other men's alleged facts and observations, and then he went occasionally astray. No later philosopher has described in clearer or more perspicuous language, than Boyle uses, the phenomena he witnessed, the experiments he performed, or the conclusions at which he arrived. Nevertheless, Boyle is intolerably tedious and prolix in all his writings, and often, likewise, very immethodical in his arrangement, and defective in logical precision. He excused himself from systematic discussion of the topics he considered, because the scholastic successors of Aristotle had retarded the progress of science by their refined subtleties and undeviating rigid adherence to false systems, as if the evil had lain not in the system being baseless, but simply in its being a system. Hence even his *Usefulness of Philosophy*, which peculiarly called for the most lucid arrangement and orderly discussion, is an undigested rambling discourse, which, instead of resembling the map which a military engineer or railway surveyor would lay down of a country, can be compared only to such a chart as a naturalist would produce, if he marked his course by tracing all the divergings from the main route, into which he was tempted by the winged insects he chased, or the rare plants he turned aside to gather.

Like the naturalist, Boyle wanders aside to tell of spiders that sting through the soles of men's boots, or to enlist his reader's sympathies in the risk of destruction which a new suit of clothes ran from his spilling, in the dark, some acid upon them, or to recount the vindication of the usefulness of philosophy which was furnished by his smelling out, still

in the dark, a bottle of hartshorn, with which he effaced the stains which the oil of vitriol had produced. Boyle's prolixity has done his reputation great injury. It was quite incurable, for besides his avowed and systematic want of system, his early habits of desultory study had unfitted him for the use of a severe logic. No restraining editor, moreover, limited him to so many sheets or pages, nor did any judicious publisher counsel terseness and condensation. The printer could not frighten so wealthy an author by the vision of his bill, and Boyle, a very Marshal Blücher, with 'Forwards' for his motto, was always in a hurry to be done with what he was at, and on to something else. He acted, accordingly, like the Frenchman, who apologized for writing a long letter because he had not time to write a short one. Boyle wrote a long treatise, and then a long preface apologizing for the length of the treatise, which might have been judiciously shortened in the time spent in writing the apology for its want of brevity. Few of the busy moderns, accordingly, have read a tithe of Boyle's six folios; no one, probably, within the last hundred and fifty years, but the corrector of the press at which Birch's edition of his works was printed. His volumes have proved a mausoleum, in which his name has been buried, not preserved; like those Egyptian pyramids, which are so immense, and within so uninviting and inaccessible, that scarcely one man in a century penetrates into their interiors far enough to read the name and the character of the king whose fame they were raised to commemorate.

Modern writers, however, if they have read little, have not hesitated in many cases to judge summarily, as if they had read all. A tendency has latterly appeared, especially in this country, to speak of Boyle as if he had been greatly overrated, had been too long remembered, had little intrinsic

merit, and deserved now to be forgotten. This depreciation of the philosopher is in part the fruit of a reaction against the extravagant praises which his contemporaries and immediate successors bestowed upon him. Those praises, however, are more extravagant in appearance than in reality. A sceptical, critical, practical age like our own, uses fewer words and more subdued expressions, even when its praise is hearty and sincere, than it was the fashion of our forefathers to employ in paying ordinary compliments. If we make this allowance, we shall find little to deduct from the estimate which was formed from the first of Boyle's genius. The able author of the 'Sketch of Boyle,' in the *Penny Cyclopædia*, has justly observed, that foreigners of the present day are not likely to be biassed in favour of the philosopher by those considerations which may insensibly warp the judgment of his countrymen. The biographer in question, accordingly, refers to Mr. Libes, author of the *Hist. Phil. des Progrès de la Physique*, Paris, 1810; as devoting a chapter to the consideration of Boyle, in which he dwells on the greatness of his physical discoveries, and the genius which he showed in making them. We may add, that Cuvier has done the same thing in the *Biographie Universelle.* Hoefer, in his *Histoire de la Chimie*, Paris, 1842, discusses in several chapters Boyle's chemical discoveries, and insists on their interest and importance. Professor Hermann Kopp, of Giessen, in his *Geschichte der Chemie*, Brunswick, 1843, gives an admirable abstract, of the same nature, but fuller than Hoefer's, and writes in the most cordial and eulogistic terms of Boyle's merits. In truth, since Europe named the air-pump and its vacuum after Boyle, down to the present day, he has had a high place assigned to him by continental philosophers of every nation. Nor have all his countrymen in later times written

disparagingly of him. One of the highest living authorities on the subject has pointed out a merit of Boyle's wholly overlooked both by his eulogists and detractors. Sir William Hamilton (of Edinburgh) has shown that Boyle was one of the first distinctly to indicate the great catholic division of the properties of body or matter into 'primary and secondary.' Sir William refers to the 'intrinsic importance' of Boyle's classification of corporeal qualities, and adds that 'they probably suggested to Locke the nomenclature which he has adopted, but, in adopting, has deformed.'[1] After such a testimony from so eminent a logician, metaphysician, and physicist as Sir William Hamilton, we need add nothing further to prove that we are not labouring under a delusion in claiming for Boyle a high and lasting place among men of science. Those who deny this, have not, we believe, read the works they criticise. The 'History of the Air-pump,' already discussed, warrants the charge. Boyle's prolixity may be an excuse for not reading his papers, but it should at the same time bar all criticism of them. They are dry enough reading at times, but they can be got through : nor need all his works be perused to enable us to perceive the amount of precious ore which lies in the midst of heaps, sometimes hills of dross.

We know no natural philosopher with whom, in quality of intellect, and habits of working, Boyle can exactly be compared. We could compound him, however, pretty well out of Dr. Joseph Black and Dr. Priestley. He had the versatility, energy, and unsystematic mode of carrying on researches of the latter. Priestley and Boyle were constantly experimenting on all kinds of things, and made many trials without a definite object, or precise expectation as to the result. Both stood before the oracle, putting endless

[1] Hamilton's edition of the Works of Dr. Thomas Reid, Note D, p. 833.

unconnected and isolated questions to the priestess, anxious for an answer, but without preconception what the answer would be. Boyle, however, paid much more attention to the reply than Priestley did, and understood its meaning a great deal better. Both were equally ingenious in devising experiments, and successful in performing them, but Priestley often totally misunderstood the phenomena he brought to light, and was led completely astray by his own experiments. Boyle resembled Black in the accuracy with which he observed results, in the caution with which he drew conclusions, and the skill with which he interpreted the phenomena he witnessed. He had the energy and versatility of Priestley, and the caution and logic of Black, but he was less versatile than Priestley, and more incautious and less logical than Black.

Boyle, however, was something more than a philosopher. He was a Christian philosopher. Foolish as this world is, it contains many philosophers ; wicked as it is, it contains many Christians ; but not many Christian philosophers. Boyle was one of the few who, from time to time, are granted to us by a kind Providence to make us wiser and better. He was not a Christian on the Sundays, and a philosopher on the week days ; a Christian over his prayer-book, and a philosopher over his air-pump : a Christian in church, and a philosopher in his laboratory ; as too many good and wise men to appearance, altogether, and in reality, too much are. He studied Nature, not as a veil hung between man and God, but as the works of Him, without whom 'was not anything made that was made.' He worshipped God, not as an 'unknown God,' such as the Greek philosophers raised an altar to, but as the Living One, the impress of whose finger he had found on every material object he had examined, 'whose ways' he better than most

men knew 'were past finding out,' but whose works he had found 'all to praise him.'

Boyle's religious writings, nevertheless, are, not a few of them, altogether unsuited to the taste of the present day. We should be afraid to put into the hands of a lively youth his 'Occasional Reflections,' and few devout men of maturer years, at all conscious of a sense of the ludicrous, would venture, we think, to peruse them. Yet an Oxford publisher, as the reader may see from the heading of our article, has chosen those very Reflections, which Swift and Butler parodied, as worthy of republication. We neither wish, nor expect for him, many purchasers.

The depth and sincerity of Boyle's piety must not be estimated by the want of good taste which appears in his religious writings, considered as literary productions. His life and his deeds are the best testimonies to his Christianity. Setting his claims as a natural philosopher aside, he has always seemed to us to resemble in many respects a gifted man of our own day. Robert Boyle and William Wilberforce had much in common, although a first glance might lead to a very different conclusion. It will be well at once to dispose of the differences between their characters, that the essential likeness in their dispositions and aims, as well as in the events of their history, may distinctly appear.

Wilberforce was a man of a singularly sunny and genial temperament, with a temper so sweet that no provocation could ruffle it, and a fancy and eloquence so fascinating, that alike in the drawing-room and in the House of Commons he was listened to with delight by all. Boyle was a grave, melancholic, formal man, whom Cowley and Davenant indeed praise for his wit, but whom Burnet speaks of as having had a certain too precise stiffness of manner even to his friends. He had no gift of speech, but on the other

hand was afflicted with a stammer, and by nature he was choleric, and subject, as we have seen, to great fits of depression.

Such differences, however, are but skin-deep. The points of resemblance are much more striking than those of difference. Boyle and Wilberforce were alike as the children of wealthy men, not high in rank by hereditary nobility, but meeting on terms of equality with those who boasted most of ancestral honours. Both were spoiled children, allowed in early life an unwise amount of freedom, and permitted to play with study in a way which they lamented in after life, and the evil effects of which they sought in vain in maturer years to remedy. Both set out on foreign travel, actuated chiefly by the wishes of relatives and the ardour of youthful curiosity. Both underwent, whilst abroad, a great spiritual transformation, which made 'all things new' for them, and returned to their own country still very young men, to devote every energy to the extension of Christ's kingdom upon earth. They mingled freely in society, were welcome in every circle, were admired for their gifts and accomplishments, and early in life were famous over Europe, the one as a philosopher, the other as a statesman. Neither of them was what would be called a business man, and both constantly lamented that they had not been trained to habits of closer application, but each contrived, from a strong sense of the value of time, and a deep conviction of duty, to go through, in his own immethodical way, a greater amount of work, than many of the most formal disciples of the red-tape school succeed in accomplishing. Both were indifferent scholars, and had no taste for verbal or philological inquiries, but the belief that the study of the Bible in the original, was the duty of every Christian who could acquire the languages in

which it was written, and a persuasion that such study would repay the student, induced each of them to become a proficient in Greek and Hebrew. In recognition of the importance of having the Scriptures translated into every living tongue, and in earnest advocacy of the claim upon the Church of Christ to send missions to the heathen, both were alike, and before their age. Their tongues, their pens, their influence with the great, their fortunes, and their sympathies, were all flung into the balance, to make the scale preponderate in favour of the claims of the destitute and benighted of mankind upon their brethren. They were alike also—Boyle, however, exceeding Wilberforce—in the catholicity of their religious opinions. Both were attached but unsectarian members of the Church of England, counting it good but not perfect. Many of their dearest friends whose Christianity was most exemplary, were Dissenters, and they did not confound dissent with schism. The one was the friend of Baxter and Penn, the other of Jay and Clarkson. May such men abound, and break down 'the middle wall of partition' which needlessly separates the true Christians of one denomination from another!

Our sketch is completed. In labours manifold, in the founding of a lecture which should vindicate the claims of Christianity upon mankind,[1] in liberal gifts to every benevo-

[1] We cannot deny ourselves the pleasure, and its author the justice, of adverting to one of the most recent works which has appeared in connexion with the Boyle Lecture, *The Religions of the World*, by the Rev. F. Maurice. This treatise is perhaps less known in the circles of Nonconformity than it deserves to be. The few minds in England that are attentive to the development of our higher theological literature, know Mr. Maurice to be one of the most accomplished writers of the age, in all topics that respect the theory of religious belief, and the relations of Christianity to philosophical systems. The work to which we have referred more than sustains his high reputation. A less speculative mind might perhaps object to it, too great a fondness for the discovery of system and order in the *disjecta membra* of non-Christian creeds and superstitions, and also a tendency shared by

lent undertaking, in large secret charities to poor scholars, and the destitute of every class, Boyle spent his fortune and his time. He looked forward to death with Christian composure and fortitude, but he trembled as a man. He had a very sensitive body, and was the victim of a cruel disorder, which he feared might rise to such an intensity in his last moments, as to overwhelm his courage and his faith. But it pleased God, as it has often pleased Him, to disappoint the fears of His doubting yet faithful servant. He had scarcely taken to his bed before the curtain fell. The agonies which should prove unendurable were never felt. The bitterness of death was not tasted. The awful tempter who had poisoned the happiness of a long life, quailed before the benignant presence of Him who is with His people even unto the end. Life ebbed away, and its dying murmur uttered only the peaceful sound, 'He giveth his beloved sleep.'

him with the whole school in the Church of England to which he belongs, to shift the centre of Christianity from the atonement to the incarnation of the Redeemer; but every candid person will be pleased with the spirit of deep and liberal sympathy, in combination with extensive learning, with which he has divined not less than investigated the peculiarities of the religions which prevail *in partibus infidelium*, and every Christian will rejoice in his able development of the resources of the gospel as the religion of humanity, which incorporates all that is natural, and sets aside all that is perverse in other beliefs, and that not by a critical eclecticism, but by a creative inspiration. We willingly pay this tribute to an able scholar, a genial thinker, a liberal divine, who has not been spoiled by the philosophy and vain deceit in which he has been much conversant, and a simple and graceful writer, who amid the current sophistication of the philosophic style has not yet learned to be ashamed of the English language.

WOLLASTON.[1]

William Hyde Wollaston, one of the ablest and most renowned of English chemists and natural philosophers, was born August 6, 1766, and died in December 1828. Seventeen years have passed away since his death, and yet no biography has appeared, although he has as wide a reputation among men of science as Sir Humphry Davy, of whom lives innumerable have been written. This has in part arisen from the comparatively retired life which Wollaston led, and the reserve and austerity of his character. He was not, like his great contemporary, a public lecturer to a highly popular institution, and thereby an object of interest, not only to men of science, but likewise to students of literature, and even to people of fashion. His life was spent in his laboratory, from which even his intimate friends were excluded : and the results of his labours were made known only by essays, published for the most part in the Transactions of the Royal Society of London. His discoveries, however, were so many, and of so important a kind, and made his name so widely known, that we cannot but wonder that no biography of him has yet ap-

[1] (1.) *The Bakerian Lecture for* 1828. On a Method of rendering Platina malleable. By W. H. Wollaston, M.D., V.P.R.S.

(2.) *Philosophical Transactions for* 1829. A Description of a Microscopic Doublet; On a Method of Comparing the Light of the Sun with that of the Fixed Stars; On the Water of the Mediterranean. By W. H. Wollaston, M.D., V.P.R.S.

peared. Two of his publications, the one containing the description of his reflecting goniometer, the other explaining a process by which platina may be rendered malleable, would alone have entitled Wollaston to a place in the roll of natural philosophers worthy of lengthened remembrance. Had he been a German, some patient, painstaking fellow-countryman would long ago have put on record all that could be learned concerning his personal history. Had he been a Frenchman, an eloquent Dumas or Arago would have read his *éloge* to the assembled men of science of the French capital, in language acceptable to the most learned, and intelligible to the most unscientific of men. His fate as an Englishman, is to have his memory preserved (otherwise than by his own works) only by one or two meagre and unauthenticated sketches, which scarcely tell more than that he was born, lived some sixty years, published certain papers, and died.

With the exception of some faint and imperfect glimpses of an austere taciturn solitary, perfecting wonderful discoveries in a laboratory hermetically sealed against all intruders, we learn almost nothing of the individuality of the worker. A few anecdotes, incidentally preserved in the lives of some of his contemporaries, contain nearly that has been published concerning his personal history.

We have been informed that, soon after Wollaston's death, all the documents and materials necessary for his biography were placed in the hands of a gentleman well qualified for the task of writing it. The expected work, however, has not appeared, and, so far as we are aware, no progress has been made towards its production. We trust that the idea of publishing a life of Wollaston has not been abandoned, and that we shall yet see his personal history placed on permanent record.

Meanwhile, we think we shall do our readers a service by bringing before them such a sketch of the philosopher as the scanty materials at our disposal enable us to furnish. Imperfect and fragmentary as it necessarily is, it will give them some idea of a very remarkable man. An experienced crystallographer can tell from a few sandlike grains, or a single detached and rounded angle, that the crystal of which they once were parts was a perfect cube, a many-sided prism, or a symmetrical pyramid. The geologist can infer from a tooth or a claw much concerning the whole animal to which it belonged. We trust that our readers will in like manner be able to piece our biographical fragments together into 'one entire and perfect chrysolite:' and that they will find the palæontologist's guiding mottos, '*Ex ungue Leonem*,' '*Ex pede Herculem*,' lead them to the conclusion that they are dealing with one of the *megatheria* among men of science.

William Hyde Wollaston belonged to a Staffordshire family, distinguished for several generations by their successful devotion to literature and science. His great-grandfather, the Rev. William Wollaston, was author of a work famous in its day, entitled, *The Religion of Nature Delineated.* His father, the Rev. Francis Wollaston of Chiselhurst, in Kent, from his own observations, made an extensive catalogue of the northern circumpolar stars, which, with an account of the instruments employed, and tables for the reductions, was published under the title of *Fasciculus Astronomicus*, in 1800.

The subject of our memoir was the second son of the astronomer, and of Althea Hyde, of Charter-house Square, London. He was one of seventeen children, and was born at East Dereham, a village some sixteen miles from Norwich, on the 6th of August 1766. After the usual prepara-

tory education, he went to Cambridge, and entered at Caius College, where he made great progress. In several of the sketches published of him, he is said to have been senior wrangler of his year ; but this is a mistake, arising out of the fact, that a person of the same surname, Mr. Francis Wollaston, of Sidney Sussex College, gained the first place in 1783. Dr. Wollaston did not graduate in arts, but took the degree of M.B. in 1787, and that of M.D. in 1793. He became a Fellow of Caius College soon after taking his degree, and continued one till his death. At Cambridge he resided till 1789, and astronomy appears to have been his favourite study there, although there is evidence to show that at this time, as at a later period, he was very catholic in his scientific tastes. He probably inherited a predilection for the study of the heavenly bodies from his father, and it was increased by his intimacy with the late astronomer-royal of Dublin, Dr. Brinkley, now Bishop of Cloyne, and with Mr. Pond, formerly astronomer-royal of Greenwich, with whom he formed a friendship at Cambridge which lasted through life.

In 1789, he settled at Bury St. Edmunds, in Suffolk, and commenced to practise as a physician, but with so little success, probably on account of the peculiar gravity and reserve of his manner, that he soon left the place and removed to London. He succeeded, however, no better in the metropolis. Soon after reaching it, a vacancy occurred in St. George's Hospital, and Wollaston became candidate for the office of physician there. The place was gained, however, by his principal opponent, Dr. Pemberton, 'who, it is said, either by superior interest, or, as is commonly supposed, by his more pleasing and polished manners, obtained the situation.' It is added in several of the notices of Wollaston, 'that on hearing of his failure, in a fit of

pique he declared that he would abandon the profession, and never more write a prescription, were it for his own father.' This statement must be received with hesitation. So staid and sedate a person as Wollaston was, is not likely to have given utterance to the hasty and intemperate expressions attributed to him; and so prudent a man would not have bound himself by a rash vow to abandon his profession, unless he had seen the prospect of occupying himself more pleasantly and profitably in another way. This account, indeed, is in direct contradiction to another; which is so far authentic, and entitled to greater credibility, that it is contained in the report of the Council of the Astronomical Society of Great Britain, presented at the anniversary meeting in 1829. In the obituary notice of Wollaston given in that report, it is mentioned, 'that he continued to practise in London till the end of the year 1800, when an accession of fortune determined him to relinquish a profession he never liked, and devote himself wholly to science.'

He had no occasion to regret the change, even in a pecuniary point of view, the only one in which his abandonment of medicine was likely to have injured him. His process for rendering crude platina malleable, which conferred so great a service on analytical chemistry, is said to have brought him more than thirty thousand pounds, and he is alleged to have made money by several of his minor discoveries and inventions.

The remainder of Wollaston's life must be referred to in terms like to those in which the sacred writer of the Book of Chronicles finishes his brief record of each Jewish king: 'Now the rest of his acts, and his deeds first and last, are written in the book of the kings of Israel and Judah.' What the book of the Jewish kings is to their lives, the

archives and records of the Royal Society are to our scientific men. Dr. Wollaston became a fellow of that Society in 1793, and was made second secretary in 1806. He was for many years vice-president, and in 1820, between the death of Sir J. Banks and the election of Sir H. Davy, he occupied the president's chair. There were not a few, indeed, among the influential members of the Society who would have preferred him to Davy as permanent chairman; but Wollaston having signified his fixed intention to decline competition, gave the whole weight of his influence to Davy, and the latter was elected.

His communications to the Royal Society are thirty-nine in number, and, along with his contributions to other scientific journals, refer to a greater variety of topics than those of any other English chemist, not excepting Cavendish. In addition to essays on strictly chemical subjects, they include papers on important questions in astronomy, optics, mechanics, acoustics, mineralogy, crystallography, physiology, pathology, and botany, besides one on a question connected with the fine arts, and several describing mechanical inventions.

We shall endeavour to give the reader some idea of certain of the more important of these papers, discussing them, however, not in their chronological order, but according to a classified list.

Five are on questions of physiology and pathology, and do not admit of popular discussion. The most curious of these is a paper on 'Semi-decussation of the optic nerves,' and single vision with two eyes. Besides its interest as a scientific essay, it is important as having been occasioned by speculations concerning the cause of a remarkable form of blindness from which Wollaston suffered, during which he saw 'only half of every object, the loss of sight being in

both eyes towards the left, and of short duration only.' This peculiar state of vision proved in the end to have been symptomatic of a disease of the brain, of which he died.

Eight or nine papers are on optics, but our limits will not allow us to discuss them.

Wollaston published two papers on astronomy, one 'On a Method of Comparing the Light of the Sun with that of the Fixed Stars,' of which we can only give the title; the other is, 'On the Finite Extent of the Atmosphere,' and is one of the most interesting physical essays on record. It was published in January 1822, in the May preceding which, a transit of Venus over the sun's disk took place. Wollaston was induced in consequence to make observations on this rare and interesting phenomenon. None of the larger observatories were provided with suitable instruments for watching it; but our philosopher, with that singular ingenuity both in devising and in constructing apparatus which we shall afterwards find to have been one of his great characteristics, succeeded by a few happy contrivances in making a small telescope completely serve the purpose. His special object in watching the passage of Venus, was to ascertain whether or not the sun has an atmosphere like that of the earth. He satisfied himself that it has not, and embodied his results in the paper, the title of which we have given.

It is a very curious attempt to decide a most difficult chemical problem by reference to an astronomical fact. The chemical question is, do the elements of compounds consist of indivisible particles or atoms, or do they not? It is a branch of the great problem which has occupied physics and metaphysics since the dawn of speculation, in vain attempts to decide either way, viz., is matter finitely or infinitely divisible? Our author undertakes to show, not only that this difficulty may be solved, but that in fact it

was solved, though no one was aware of it, as early as the discovery of the telescope, and Galileo's first observation of the eclipses of Jupiter's moons.

His mode of reasoning is as follows. If our air consist of an infinite number of particles, then as these are known to be self-repulsive, there can be no limit to the amount of its expansion. It will spread out into space, on every side, and be found surrounding each of the heavenly bodies.

If, on the other hand, the atmosphere consist of a finite number of molecules or atoms, it will find a limit at no great distance from the earth. For the force of repulsion between the atoms will rapidly diminish as they recede from each other, till it become insufficient to oppose the counteracting force of gravity. The air will then cease to expand, and present a row of bounding molecules, prevented from falling towards the earth by the repulsion of the particles between it and them, and from receding from the earth by their own weight. The conclusion from this reasoning is, that if astronomy can show that any one of the heavenly bodies has not an atmosphere of the same nature as ours, chemistry will be entitled, and indeed compelled, to infer, first, that our atmosphere, and then that all matter, consists of finitely divisible particles or true atoms.

The astronomical problem is easily and speedily solved. The moon is *too near* us, to permit of observations of the necessary kind being made, as to her possession of an atmosphere similar in constitution to ours : but according to telescopic observation, she is a naked globe. The phenomena presented when Venus or Mercury passes close to the sun, certify that he has no atmosphere like that of the earth ; but his high temperature, and its possible effect on an atmosphere, if he have one, somewhat lessen the value of the fact. Jupiter, however, and his five moons, admit of

observations which make it certain that our aërial envelope has not reached to that heavenly body.[1] When his satellites suffer eclipse by passing behind him, they appear, to a spectator on the earth, to move across his disk till they reach its edge, when they instantaneously disappear. When they reappear after moving round him, they emerge in a moment from behind his body, and start at once into full view. Had Jupiter an atmosphere like ours, the occultation of his satellites would not occur as it is observed to do. Our sun, when he sinks below the horizon, remains visible to us by the light bent up or refracted to our eyes, through the transparent air, and twilight slowly darkens into night. In like manner, long before the rising sun would be seen if our globe were naked, the air sends up his rays to our eyes, and he becomes visible. If Jupiter had an atmosphere like that of the earth, each of his moons, instead of disappearing at once behind his disk, would exhibit a twilight recession, and slowly wane away; when it returned, it would be seen much sooner, after being lost sight of, than it is at present, and would gradually wax brighter and brighter till it came fully into view. In other words, the atmosphere of Jupiter would send back the light of the satellite to us, after the latter disappeared behind the planet; and would send forward that light before the moon reappeared. Wollaston shows that, in the case last supposed, the fourth satellite would never be eclipsed, but would remain visible when at the very back of the planet.

[1] The reader will observe that the argument is based, not on the fact of the heavenly bodies lacking atmospheres, which some of them may possess, but on their wanting atmospheres of the *same* nature as ours. We cannot apply chemistry to ascertain whether oxygen and nitrogen, or the other gases of our atmosphere, envelop distant globes; but we can bring optics to discover whether a power to refract light such as our air possesses, exists around any of these spheres. From the text it will be seen that no such power has been observed in any case.

It is certain, then, that the earth's atmosphere is limited, and, according to Wollaston, it is equally sure that matter is only finitely divisible.

The paper we are discussing excited great attention among men of science ; and for a long period, though few implicitly assented to the validity of the argument, no one appeared able to detect any fallacy in its reasoning. It was commented on by Faraday, Graham, Turner, and Daubeny, as an important contribution to chemistry ; and referred to by Dumas as the only attempt which had been made in modern times to decide by physics the question of the finite or infinite divisibility of matter. More recently, it has been shown that the fact that the atmosphere is limited will not justify the conclusion which Wollaston deduced from it.

It has been suggested by Dumas, following out the views of Poisson, that the low temperature which is known to prevail in the upper regions of the atmosphere, may be such at its boundary as to destroy the elasticity of the air, and even to condense it into a liquid or freeze it into a solid. The outer envelope of our atmosphere is thus supposed to be a shell of frozen air. If this view be just, our atmosphere is limited, not because it consists of atoms, but simply because a great cold prevails in its upper regions.

Professor Whewell has shown that Wollaston was not entitled to assume that the law which connects the density of the air with the compressing force is the same at the limit of the atmosphere as it is near the surface of the earth. He suggests a different law which may prevail, and which would terminate the atmosphere without the assumption of atoms.

Lastly, it has been pointed out, that though all Wollaston's postulates were granted him, they would only entitle him to infer that the atmosphere consists of a finite number

of repelling molecules. To establish this, is to establish nothing. We are still on the threshold of the argument. Each molecule supplies as good a text whereon to discuss the question of divisibility, as the whole atmosphere out of which it was taken. The point which most of all demanded proof, namely, that the molecule was an atom, was the very one which Wollaston took for granted.

Beautiful, then, and certain as are the astronomical facts brought to light by Wollaston, they supply no decision of the question of the divisibility of matter. That problem still presents the same twofold aspect of difficulty which it has ever exhibited. If we affirm that matter is infinitely divisible, we assert the apparent contradiction, that a finite whole contains an infinite number of parts. If, pressed by this difficulty, we seek to prove that the parts are as finite as the whole they make up, we fail in our attempt. We can never exhibit the finite factors of our finite whole ; and the so-called atom always proves as divisible as the mass out of which it was extracted. Finity and infinity must both be believed in ; but here, as in other departments of knowledge, we cannot reconcile them.

The greater number of Wollaston's strictly chemical papers, with the exception of those referring to physiology and pathology, are devoted to the exposition of points connected with the chemistry of the metals. He was the discoverer of palladium and rhodium, once interesting only as chemical curiosities, but now finding important uses in the arts. He discovered, also, the identity of columbium and tantalum. He was the first to recognise the existence of metallic titanium in the slags of iron furnaces ; and he is the deviser of the important process by which platina is rendered malleable. He published, also, analyses of meteoric iron, and showed that potash exists in sea water.

The majority of the essays in which these discoveries were made known, are of too limited and technical a character to admit of notice in this paper. There is one of them, however, that 'on a process by which platina may be rendered malleable,' which cannot be dismissed without a word of explanation.

It must seem curious to a general reader, that much value should be attached to a mere metallurgical process, however ingenious. He will be further perplexed by learning that the Royal Society, passing over Wollaston's claims to reward, as the author of important speculative, and purely scientific papers, selected this essay as the object of their special commendation. The strong words used by the Council of the Society are, 'Your Council have deemed themselves bound to express their strong approbation of this interesting memoir by awarding a royal medal to its author, and they anticipate with confidence a general approbation of what they have done.' It may help the reader to understand why the paper in question is esteemed so highly if he be made aware of the following facts.

Among other bodies which the alchemists of the middle ages thought it possible to discover, and accordingly sought after, was a Universal Solvent, or *Alkahest* as they named it. This imaginary fluid was to possess the power of dissolving every substance, whatever its nature, and to reduce all kinds of matter to the liquid form. It does not seem to have occurred to these ingenious dreamers to consider, that what dissolved everything, could be preserved in nothing. Of what shall we construct the vessel in which a fluid is to be kept, which hungers after all things, and can eat its way through adamant as swiftly as water steals through walls of ice? A universal solvent must require an equally universal *non solubile* in which it may be retained for use.

The modern chemist's desire has lain in the opposite direction from that of his alchemical forefather. It is the *non solubile*, not the solvent, that he has sought after, and Wollaston supplied him with that in malleable platina. Long before the close of last century, the chemical analyst found the re-agents he had occasion to make use of, alkahests or universal solvents enough, for the vessels in which he could contain them. For the greater number of purposes, glass and porcelain resist sufficiently the action of even the strongest acids, alkalies, and other powerful solvents. In some cases, however, they are attacked by these, and cannot be employed in accurate analysis. Whenever, moreover, it is necessary to subject bodies to a high temperature along with active re-agents, as, for example, in the fusion of minerals with alkalies, porcelain can seldom be employed, and is often worse than useless.

It was in vain that chemists had recourse to silver and gold, as substitutes for the insufficient clay in the construction of their crucibles. These metals melt at comparatively low temperatures, and, before a sufficient heat can be attained to fuse the more refractory substances enclosed in them, they run into liquids, and the crucible and its contents are lost in a useless slag.

In consequence of this insufficiency of his tools, the analytical chemist was brought to a complete stand. Whole departments of his science lay around him unexplored and unconquered, tempting him by their beauty and their promise. He could only, however, fold his arms and gaze wistfully at them, like a defeated engineer before a city which his artillery and engines have failed to subdue.

It was at this crisis that Wollaston came forward to put a new weapon into the hands of the chemical analyst. Several years before he turned his attention to the subject,

scattered grains of a brilliant metal had been found in the sands of certain of the South American rivers. To this, from its resemblance to silver, or in their language Plata, the Spaniards gave the name of Platina, or little silver. This metal was found to resist the action of nearly every substance except Aqua Regia; to suffer no change, nor to become rusted by protracted exposure to the atmosphere; and to be perfectly infusible by the most powerful forge or furnace.

Here, then, was a substance for the chemist's crucible, could a method of working it only be discovered. But the very properties which made its value certain, if it were wrought into vessels, forbade its being easily fashioned into them. It occurred in nature only in small grains, which could not be melted, so that it was impossible, as with most other metals, to convert it into utensils by fusion. Neither was it possible by hammering to consolidate the grains into considerable masses, so that vessels could be beaten out of them, for the crude metal is very impure. Accordingly, it happened, that for years after the value of platina had been discovered, it could not be turned to account. Whole cargoes of the native metal, although it is now six times more costly than silver, are said to have lain unpurchased for years in London, before Wollaston devised his method of working it.

That method was founded upon the property which platina possesses of agglutinating at a high temperature, though not melted, in the way iron does, so that, like that metal, it can be welded, and different pieces forged into one. This property could not, however, be directly applied to the native grains, owing to their impurity and irregularity in form.

Wollaston commenced by dissolving the metal in aqua

regia; purified it whilst in solution from the greater number of accompanying substances which alloyed it; and then, by the addition of sal ammoniac, precipitated it as an insoluble compound with chlorine and muriate of ammonia. When this compound was heated, these bodies were dissipated in vapour, and left the platina in the state of a fine black powder, which was further purified by washing with water.

It was only further necessary to fill a proper mould with this powder well moistened, and to subject it to powerful compression. By this process the powder cohered into a tolerably solid mass, which was gently heated by a charcoal fire, so as to expel the moisture and give it greater tenacity. It was afterwards subjected to the intensest heat of a wind-furnace, and hammered while hot, so as completely to agglutinate its particles, and convert it into a solid ingot. This ingot or bar could then be flattened into leaf, drawn into wire, or submitted to any of the processes by which the most ductile metals are wrought.

We have passed over unnoticed many practical minutiæ essential to the success of Wollaston's process. The reader is more concerned to know that the platina crucible has been one of the chief causes of the rapid improvement which chemistry has recently undergone, and that it is an indispensable instrument in the laboratory. The costliness of the metal has not forbidden its application to manufacturing operations even on the largest scale. In the oil of vitriol works, stills of platina are made use of for distilling sulphuric acid, each of which, though holding only a few gallons, costs above a thousand pounds. A coinage of platina was introduced into the Russian dominions, which possess valuable supplies of its ores; but though roubles and other coins struck in it, occasionally reach this country as curiosities, we understand that the coinage has been withdrawn

by the imperial government, in consequence of the fluctuations that occur in the value of the metal.

In our own country, from the great consumption of platina in chemical processes, its value has rapidly risen even within the last few months; but it is constantly shifting.[1] Nothing but its rarity and costliness prevent its application to the construction of every kind of culinary vessel, for which its purity, cleanliness, and enduringness especially fit it. A thousand other uses would be found for it, if it were more abundant.

Were it now the custom to honour men after death according to the fashion of the Greeks and Romans, Wollaston's ashes would be consigned to a gigantic platina crucible, as to a befitting and imperishable sepulchral urn.

His other chemical papers are all important. One of them, 'on the chemical production and agency of electricity,' proved, by singularly ingenious and beautiful experiments, that identity of voltaic and friction electricity, which Faraday has since confirmed by still more decisive trials. The others had reference chiefly to the atomic theory, which Wollaston was a great means of introducing to the favourable notice of chemists. One was 'On superacid and subacid salts,' and contained one of the earliest and most convincing proofs which can be given of the existence of such a law of multiple proportion, as Dalton had announced. The other, on 'A synoptical scale of chemical equivalents,' first brought the laws of combination within the reach of the student and manufacturer.

[1] Platina costs at present [1846], in the state of ingot or bar, from 30s. to 35s. per ounce, wholesale. Manufactured articles from 32s. to 42s. per ounce, also wholesale. The retail prices are from 5s. to 10s. higher. Virgin silver sells at 5s. 8d. per ounce, wholesale; at 9s. per ounce, retail, when manufactured. Sterling silver is worth 4s. 11d. per ounce.

Wollaston published three papers on the shapes of crystals, and on the mode of measuring them. No branch of science is less inviting to the general student than crystallography. Nevertheless, we must be allowed to refer briefly to one of Wollaston's essays on that subject. The most superficial sketch of the philosopher whose works we are considering, would be inexcusably defective if it passed it by.

The paper we refer to is entitled, 'Description of a Reflective Goniometer,' and next to that containing the account of the platina process, is perhaps Wollaston's most important contribution to science. It is much more difficult, however, to convey an idea of its value, than it was in the case of that essay.

There are no bodies, perhaps, more interesting to a greater number of persons than crystals. The rarer native ones which we name gems, rank with the precious metals in expressing by the smallest bulk the greatest commercial value. The precious stones have been hallowed in the minds of many from their earliest days, by the terms in which they are alluded to in the Bible. The lavish use made of them in adorning the dress of the Jewish high-priest; the manifold references to them in the books of the prophets, and in the more impassioned writings of the Old Testament; and most of all the striking and magnificent way in which they are referred to by St. John as types of the glories of the world to come, must satisfy even the most careless reader of the Scriptures, that God has marked them out as emblems of indestructibility, rarity, worth, beauty, and purity. Their appropriateness for this purpose must strike every one. The painter has counted it a triumph of his art to imitate even imperfectly their colours and brilliancy. Poets have all loved to sing of them. Beauty in

every age and clime, barbaric and civilized, however much she has loved caprice in other things, and has complained of ennui and satiety, seems never to have tired of her rubies and emeralds, or to have grown weary of admiring her 'family diamonds.'

And if the symbolical, æsthetical, fictitious and commercial value of crystals has been great, their worth to the man of science has not been small. The mineralogist counts them the most precious treasures of his cabinet. The geologist defines and marks out rocks by them. The electrician has detected curious phenomena by means of their aid. The investigator of the laws of heat finds them of indispensable service in studying his subject. The optician is indebted to them for the greatest generalization of his science, and for the discovery of many of its most delightful, though most intricate departments. Recently they have been declared to present remarkable and hitherto unsuspected relations to magnetism. The chemist considers a knowledge of crystallography absolutely requisite, not merely as enabling him to identify substances without the trouble of analysing them, but likewise as unfolding analogies of the greatest importance in relation to the classification of chemical compounds. Medical men have discovered that, in many dangerous disorders, crystals show themselves in the fluids of the body, and now study their shapes with the utmost care as a means of detecting and alleviating disease. Finally, the greatest mathematicians have counted it a worthy occupation to investigate the forms and geometrical relations of crystals. We need only remind our scientific readers of the labours of Huygens, Young, Fresnel, Arago, Brewster, Sir William Hamilton of Dublin, Herschel, Mohs, Weiss, Mitscherlich, Faraday, not to mention a multitude of others, to satisfy them that we have

not overstated matters. The undulatory hypothesis of light, the laws of its double refraction, and those of its polarization, have been suggested or discovered by observations with crystals. The same remark applies to the laws of the radiation and polarization of heat, and with limitations might be extended to other branches of natural philosophy. There is not, indeed, a single physical science which has not an interest in crystallography.

From this brief statement it will appear, that nearly every class of scientific men was certain to gain by the invention of an instrument which promised greatly to facilitate, and to render more accurate, the study of crystals. We will not say that the poet, the painter, or the beauty owed Wollaston any thanks. They did not, at least, immediately; but in the end it may appear, and it would not perhaps be difficult to demonstrate, that they are all gainers by the progress of science. We return, however, to the reflective goniometer.

A goniometer, as its name implies (*γωνία*, an angle, *μέτρον*, a measure), is an instrument for measuring angles. The appellation, though susceptible, of course, of much wider application, is restricted to an apparatus for measuring the angles of crystals. Different goniometers were in use before Wollaston invented his, but they were comparatively rude, and could only be applied to large crystals. This limitation of their employment was doubly disadvantageous. Many substances can be obtained only in minute crystals. In every case, small crystals are *ceteris paribus* more perfect than large ones. Wollaston's instrument not only applied to very diminutive crystals, but gave more accurate results the smaller the crystal was, provided only it were visible. It was able to do this from the peculiarity of its principle, which lies in this, that instead of measuring the angle

formed by the meeting of two faces of a crystal directly, it measures the angle formed by the meeting of rays of light reflected from them. It requires, in consequence, only that the crystal shall be large enough to have visible faces, and that these shall be sufficiently smooth to reflect light.

When Wollaston published the account of his goniometer, he stated as an evidence of its superiority to those previously in use, that whereas a certain angle of Iceland spar was reputed to be of one hundred and four degrees, twenty-eight minutes, forty seconds, it was in reality of one hundred and five degrees.

It cannot but seem surprising that it should be of interest to a mineralogist or chemist, to know that the angle of a crystal is by half a degree greater or smaller than it has been supposed to be. The importance of the observation arises out of the fact, that a great number of substances which assume the solid form affect perfectly regular shapes, or, as we say, crystallize. The figures which they thus present are not inconstant and uncertain, but, within prescribed and narrow limits, are perfectly fixed and invariable. Common salt, for example, the greater number of the metals, and many other bodies, when they occur as crystals, show themselves as cubes, or solid six-sided figures, with all the faces squares, and all the angles right angles. The well known doubly refracting Iceland spar (carbonate of lime) crystallizes in an equally regular and perfect, but different shape. Its crystals are six-sided, but the faces are rhombs, or resemble the diamond on a pack of cards, and its angles are not right angles. From extended observations on the crystalline shapes of bodies, the important law has been generalized, that 'the same chemical compound always assumes, with the utmost precision, the same geometrical form.' This enunciation of the law must be accepted with

certain important qualifications and exceptions, which our limits do not permit us to dwell upon. This one point, however, we are anxious to explain: the constancy of form affirmed to exist in crystals does not manifest itself 'in equality of the sides or faces of the figures, but in the equality of the angles.' It is the angle, therefore, and not the face of a crystal, which is important; the latter *may* vary, the former *must* not; hence the value of a goniometer, or angle measurer.

Again, many crystals have the same general shape. A very common form, for example, is an octahedron, or double four-sided pyramid, arranged like two Egyptian pyramids placed base to base. But though the general configuration is similar, the angles at which the faces of the pyramids incline towards each other are different in different substances, and distinguish each crystal from all its fellows. Yet the differences in angular inclination, though constant, are often very small; hence the importance of the reflective goniometer, as enabling the observer to detect the slightest difference in angular value between apparently similar crystals. For the trouble of a tedious analysis, and the sacrifice of perhaps a rare substance, we are thus frequently able to substitute the simple device of measuring the angles of its crystals.

The fact has a general interest also. To the law which the goniometer has discovered we are indebted for the exquisite symmetry and perfection of shape which make crystals, like flowers, delightful objects merely to gaze at. They may be crushed to fragments, or dissolved in fluids, or liquefied by heat, or dissipated in vapour, but they grow up again like trees from their roots, or flowers from their seeds, and exhibit their old shapes with a fidelity and exactitude of resemblance, which no tree or flower ever

showed or can show. We heard much of the restoration of the recumbent warriors in the Temple church of London, and still more of the skill shown in piecing together the broken fragments of the Portland vase ; but all such restorations are poor and faint imitations of the art, with which nature not only restores but reproduces the works of her chisel.

Were all the crystals in the world reduced to dust, in good time they would each re-appear. The painter and the poet would not only find the tints, and play of colour, and sparkle, exactly as before, but the mathematician would try in vain to discover the smallest fractional difference in the value of their angles. Unity in variety is the voice of all nature ; but in the case of crystals, the unity almost pushes the variety aside.

To descend from these speculations, the reader will understand, that as every crystallizable substance has an unchangeable form peculiar to itself, the crystalline figure of a body is an important character by which it may be recognised and identified.

But this is the lesser service which the reflective goniometer has rendered to science. Early in this century, a great German chemist, Mitscherlich, comparing the results obtained by Wollaston's instrument, with those procured by analysis, in the case of crystalline bodies, discovered a very curious and unexpected law. It appeared, that when substances resemble each other in chemical characters, their crystalline forms are also similar. When the similarity in chemical properties is very great, the shapes become absolutely identical. It is a very singular circumstance, which no one appears to have in the least anticipated, that where two closely-allied bodies, such as arsenic and phosphorus, unite with the same third substance, they should

produce identical forms when the respective compounds are crystallized. Each face of the one slopes at the same angle as the same face of the other. A mould of a crystal of the one would fit a crystal of the same size of the other. A goniometer set at the angle of the one, would exactly measure the angle of the other. Such crystals are named isomorphous, a Greek word synonymous with the Latin one, similiform, also made use of.

Taught by this law, the chemist, to his astonishment, found himself able to ascertain chemical analogies by measuring angles of crystals, and supplied with a means of controlling and explaining the results of analyses, which otherwise seemed only to lead to contradiction and confusion. Crystalline form is now one of the first things attended to in classifying chemical substances, and is the basis of most of our attempts to arrange them into groups and natural families.

We cannot delay on this curious subject. Suffice it to say that the announcement by Mitscherlich of the law of isomorphism at once overthrew the prevailing systems of mineralogy, and demanded their complete reconstruction. It changed also the aspect of chemistry, and where its influence on that science will end we cannot yet tell.

It deserves especial notice, but has never obtained it, in histories of the progress of chemistry, that he who, by his gift of the platina crucible, enabled his brethren to extend the whole science, and especially to subject every mineral to analysis, by his other gift of the reflective goniometer showed them how to marshal their discoveries. The latter instrument has been to the chemist like a compass-needle or theodolite to the settlers in a strange country. By means of it, he has surveyed and mapped out the territory he has won, so that new comers may readily understand the

features of the district; and has laid down pathways and roads, along which his successors may securely travel.

A mere list of papers is a dull thing, of no interest to those acquainted with the papers themselves, and of little value to those who are not. The reader, however, must bear with us a little, whilst we bring briefly before him three other essays by Wollaston; they are all curious, and, besides their intrinsic value, are important as illustrating the versatility of his mind, and the singular accuracy of all his observations.

One of them is on the interesting and poetical subject of 'Fairy Rings.' Most persons in this country must be familiar with the circles of dark green grass, which are frequently seen in natural pastures, or on ground which has long lain unploughed. They are particularly abundant on commons and in sheep-walks, such as the chalk-downs in the south of England. Their dimensions are so great, and they are so symmetrical, and so much darker in colour than the surrounding herbage, that they never fail to attract the attention of even the most careless passer by. These circles, a beautiful rural superstition supposes to have been marked out by the feet of fairies, whirling round in their midnight dances: they have, in consequence, been named fairy rings. It is well known, also, that they gradually increase in dimensions: in certain cases, even by as much as two feet in a single year. A believer in elves might suppose that the fairies, from time to time, admitted their children to their pastimes, when they were done with the dancing-school and fit for presentation, or in other ways added new guests to their parties, and required more spacious waltzing-ground.

These beautiful and mysterious circles the chemist would not leave to the poet. Keats has complained that—

> 'There was a glorious rainbow once in heaven ;
> 'Tis numbered now amongst the catalogue
> Of common things.'

Science, which would not spare the rainbow, has had no mercy on the fairy rings ; though, in truth, both the one and the other still are, and ever will be, as truly the possession of the poet as they were of old. There is no one, we suppose, who does not sympathize with the poetical rendering of the fairy ring ; and no one, probably, who does not at the same time wish to know what the scientific version is also. Wollaston furnished us with the latter. He was led to form the opinion we are about to state, by noticing 'that some species of fungi were always to be found at the margin of the dark ring of grass, if examined at the proper season.' This led him to make more careful observations, and he came to the conclusion that the formation of the ring was entirely owing to the action of the fungi in the following way. In the centre of each circle, a clump or group of toadstools or mushrooms had once flourished, till the soil, completely exhausted by their continued growth on it, refused to support them any longer. The following year, accordingly, the toadstools which sprang from the spawn of the preceding generation, spread outwards from the original spot of growth towards the unexhausted outer soil. In this way, a barren central place came to be surrounded by a ring of fungi, year by year increasing in diameter, as it exhausted the earth it grew upon, and travelled outwards in search of virgin soil. But this was not all. The toadstools, as they died, manured or fertilized the ground, so that, although for a certain period the place where they had grown was barren, by and by the grass flourished there more luxuriantly than elsewhere, and manifested this by its greater length and deeper colour.

In this way, each circle of mushrooms came to be preceded by a ring of withered grass, and succeeded by one of the deepest verdure, and as the one increased the others did also.

On Salisbury plain, near Stonehenge, where, as in a hallowed and befitting locality, fairy rings abound, we have tested the truth of Wollaston's view. The sides of the low mounds which cover that plain are variegated by the circles in question. A few are imperfect; quadrants and semicircles; the greater number wonderfully symmetrical, and to appearance completely circular. The latter exhibit with great uniformity the phenomena which Wollaston describes. A plot of grass, resembling in tint and appearance the ordinary herbage of the down, stands in the centre of a dark green ring five or six feet in diameter. This is fringed by a forest of fungi, and they in their turn are bounded by a circle of stunted, withered grass. This last phenomenon was quite in keeping with Wollaston's theory of the origin of fairy rings. He observes, that 'during the growth of fungi they so entirely absorb all nutriment from the soil beneath, that the herbage is often for a while destroyed, and a ring appears bare of grass surrounding the dark ring; but after the fungi have ceased to appear, the soil where they had grown becomes darker, and the grass soon vegetates again with peculiar vigour.' These views of Wollaston have been beautifully confirmed by the recent researches of Professor Schlossberger of Tübingen, into the chemical composition of the fungi, by which it appears that they contain a larger quantity of nitrogen, of phosphates, and of other salts, than any of our cultivated vegetables. In consequence of this, they must exhaust the soil more when they grow on it, and on the other hand, fertilize it more, when restored to it, than any other plants. Dr. Schlossberger

has accordingly recommended the employment of the fungi as manures.[1]

We conclude this subject by remarking that our great poet, who had an eye for everything, connects fairy rings and mushrooms together, almost as if he had anticipated Wollaston. Our readers will remember the passage in *The Tempest*:—

> 'You demy-puppets, that
> By moonshine do the green sour ringlets make,
> Whereof the ewe not bites; and you, whose pastime
> Is to make midnight mushrooms.'

In another, and one of the most curious of his papers, Wollaston again plays the part of disenchanter of a poetical fancy.

It is entitled, 'On the apparent direction of the Eyes of a Portrait.' Into this essay we cannot enter at length, but it deserves a word of notice. One large part of it is occupied in showing that we are unconsciously guided in our estimate of the direction in which the eyes of another are turned, not merely by the position of the iris (or coloured circle) and whites of these eyes, but likewise by the direction of the concurrent features, particularly those which are more prominent, as the nose and forehead. However unexpected this statement may be, or perplexing the explanation of it, Wollaston puts it out of the power of the least credulous of his readers to deny the fact, by the plates which accompany his paper. In these he shows that the same pair of eyes may be made to look up, or down, or to either side, merely by altering the direction of the nose and

[1] We have seen fields lying fallow in the south of England, because, as was alleged, they would not bear crops, although they were thickly covered with edible mushrooms. Where the latter grow freely, wheat, and the other grains, are certain to flourish also.

forehead which accompany them. In this paper, also, he supplies an explanation of the familiar fact, that 'if the eyes of a portrait look at the spectator placed in front of the picture, they appear to follow him in every other direction.'

We need not remind the reader how many allusions are made to this optical phenomenon in the works of our poets and novelists, with whom it has ever been a favourite engine for cheering, terrifying, or instructing their heroes. Here, for example, is one of Sir Walter Scott's many references to it. When Colonel Everard visited Woodstock lodge, where an ancient family portrait hung upon the walls, 'he remembered how, when left alone in the apartment, the searching eye of the old warrior seemed always bent upon his, in whatever part of the room he placed himself, and how his childish imagination was perturbed at a phenomenon for which he could not account.'

It did not escape Shakspere. To take a single case. When Bassanio opens the leaden casket, and beholds Portia's portrait, he exclaims,

> 'Move these eyes?
> Or whether, riding on the balls of mine,
> Seem they in motion?'

A beautiful poem of Mrs. Southey's, 'On the removal of some Family Portraits,' turns almost entirely on the subject we are discussing. The explanation is very simple. The only portraits which exhibit the ubiquity of look referred to, are those which have the face and eyes represented as directed straight forwards. A certain deviation from absolute straightforwardness of look may occur, without the phenomenon disappearing, although in that case it will be less apparent; but if the face and eyes are much turned to one side, it is not observed. In a front face, the same breadth of forehead, cheek, chin, etc.,

is depicted on either side of the nose, considered as a middle line. The eye, also, is drawn with its iris or coloured ring in the centre, and the white of the eye shown to the same extent on each side of the iris. In a countenance so represented, if the eye appear fixed on the spectator when he stands in front of the portrait, it will continue to gaze on him, from whatever point he regards the picture. If, for example, he place himself far to the one side of the painting, the breadth of the face will appear much diminished. But this horizontal diminution will tell on the whole face equally, and will not alter the relative position of its parts. The nose will still appear with as much breadth of face on the one side as on the other, and therefore stand in the centre. The iris will still exhibit the same breadth of white to the right and to the left, and continue therefore to show itself in the middle of the eye. The countenance, in fact, will still be directed straight forward, and its expression remain unchanged.

One other reference will conclude our discussion of Wollaston's Essays. The last paper we mention is, 'On Sounds inaudible to certain Ears.' Its object is to point out, that while, in the natural healthy state of the ear, there seems to be no limit to the power of discerning low sounds, in many persons who are otherwise quite free from deafness, there exists a total insensibility to high or shrill notes, so that they are quite deaf to these. The hearing of different persons was found by Wollaston to terminate at a note four or five octaves above the middle E of the pianoforte. His own hearing ceased at six octaves above that note. Those who were thus deaf to high notes were, in consequence, quite insensible to the chirping of the grasshopper, the cricket, the sparrow, and the bat. With these observations Wollaston connects a beautiful speculation as to the possibility

of insects both emitting and listening to shrill sounds, which we never hear; whilst they, in like manner, are totally deaf to the graver notes which only affect our ears. We quote his own words:—

'The range of human hearing includes more than nine octaves, the whole of which are distinct to most ears, though the vibrations of a note at the higher extreme are six hundred or seven hundred times more frequent than those which constitute the gravest audible sound.

'As vibrations incomparably more frequent may exist, we may imagine that animals like the grylli (grasshoppers, crickets, mole-crickets, etc.), whose powers appear to commence nearly where ours terminate, may hear still sharper sounds which we do not know to exist; and that there may be insects hearing nothing in common with us, but endued with the power of exciting, and a sense that hears the same vibrations which constitute our ordinary sounds, but so remote, that the animal which perceives them may be said to possess another sense, agreeing with our own, solely in the medium by which it is excited, and possibly wholly unaffected by those slower vibrations of which we are sensible.'

This seems to us a striking and beautiful idea, and suggests many thoughts. It is in a fine sense a fulfilment of St. Paul's declaration, 'There are, it may be, so many kinds of voices in the world, and none of them is without signification.'

Such is a most imperfect list of the additions made by a single philosopher to the scientific literature of our country; and he a private gentleman, working without help from Government, or any other extrinsic aid. Several of the essays we have referred to, were read before the Royal Society of London in the last year of the author's life,

under circumstances which invest them with peculiar interest. Towards the latter part of the year 1828, Wollaston became dangerously ill of the disease of the brain of which he died. His complaint was a painful one, and it speedily showed such symptoms as satisfied the sufferer himself that death was at hand. He acted on the information as if the warning of coming dissolution had been accompanied by the same advice which was given to King Hezekiah in similar circumstances, 'Set thine house in order, for thou shalt die and not live.' Finding himself unable to write out an account of such of his discoveries and inventions as he was reluctant should perish with him, he spent his numbered hours in dictating to an amanuensis an account of some of the more important of them. These parting gifts of a dying philosopher to his brethren will be found in the papers bearing his name which are printed in the Philosophical Transactions for 1829. We have placed their titles at the head of our article. In one of them he makes a touching allusion to the unaccustomed haste which he had been obliged to exhibit in drawing it up. No indications of haste, however, appear in the essay in question, or in any of the others referred to. One of them is the account of the process for working platina, and like Wollaston's other papers, is a model of what a physical essay should be.

These were not his only legacies to science. Shortly before his death, he wrote a letter to the secretary of the Royal Society, informing him that he had that day invested, in the name of the Society, stock to the amount of £1000. The interest of this money he wished to be employed in the encouragement of experiments in natural philosophy. A Wollaston medal is accordingly given periodically by the Royal Society.

In the June before his death, he was proposed as a mem-

ber of the Astronomical Society of London; but, according to the rules of that body, he could not have been elected before their last meeting for the year. When the Society met in November 1828, however, the alarming situation of his health, and the great probability of his dissolution previous to the December meeting, induced the Council at once to recommend to the assembled members a departure from the established rule, and that the election should take place at that sitting. This was done, and received the unanimous sanction of the meeting, which insisted on dispensing with even the formality of a ballot. Dr. Wollaston, then within a few days of his death, acknowledged this feeling and courteous act by presenting the Society with a valuable telescope, which he greatly prized. It originally belonged to his father, and had been subsequently improved by the application to it of an invention of his own, that of the triple achromatic object-glass, a device on which astronomers set great value.

It is impossible to turn from the record of these incidents, without a feeling of strong admiration of the old Roman-like resolution and calm courage with which the suffering philosopher waited for death. We are all too apt to admire only the active agonistic courage of the battle-field, or other arena of energetic and laborious warfare or struggle; and are prone to let our imaginations kindle over pictures of warriors dying at the moment of victory, covered, as we are pleased to say, with glory. It is well that we should admire these, for so noble a quality as courage must be honoured in all its rightful manifestations. Nevertheless, there are not a few who would prove heroic enough before a visible foe, but would quail before the solitary approach of the 'Last Enemy.' They could endure even to the death, when surrounded by hundreds involved in the same peril, and stirred by the same impulse as themselves; but would lack some-

thing of their courage if the influence of numbers, and the sympathy of fellow-sufferers were gone, and the excitement of active and manifest struggle were wanting. There are not many who, laid on a sick-bed as Wollaston was, and certain that recovery was hopeless, would have so risen above the terror of death, and the distraction of pain, as to work as if health were in possession, and long life in prospect. The great majority would think they did well if they submitted to their fate with some show of decent gravity, and made no unmanly complaint; whilst every solace that could be furnished was applied to smooth the way to the tomb. We cannot, therefore, but highly honour the resolute man of science, who did not permit sickness, or suffering, or coming death, to prevent him from putting on record the otherwise lost knowledge, which he thought might serve the cause of truth and benefit his fellow-men.

It would have been in the highest degree interesting to have known what were the grounds of this notable courage, and with what feelings Wollaston not only prepared to leave this world, but looked forward to a world to come. We long to learn whether it be but constitutional calmness and stoicism such as a Greek or Roman might have shown, or fortitude such as only a Christian can display, that we are called on to admire in the dying philosopher. But none of those who alone were entitled to speak on this point have given us information concerning it; and we forbear to form any conjectures. Whencesoever derived, Wollaston's stedfast resolution continued to the end. When he was nearly in the last agonies, one of his friends having observed, loud enough for him to hear, that he was not at the time conscious of what was passing around him, he immediately made a sign for a pencil and paper, which was given him. He then wrote down some figures, and, after

casting up the sum, returned them. The amount was right. He died on the twenty-second of December 1828, aged sixty-two, a few months before his great scientific contemporaries, Sir Humphry Davy and Dr. Thomas Young. After death, it appeared that that portion of the brain from which the optic nerve arises was occupied by a large tumour. If we are right in thinking that the singular one-sided blindness from which he sometimes suffered was an early symptom of this malady, it must have proceeded very slowly, for his paper on the semi-decussation of the optic nerves was published in 1824. It is interesting, for the sake of psychology, to know, that in spite of the extensive cerebral disease referred to, Wollaston's faculties were unclouded to the last.

There remains but little to be told. No picturesque incidents or romantic stories adorn Wollaston's biography, and but few characteristic anecdotes have been preserved. His days were spent with entire devotion to science, between his laboratory and his library. For it was little better than an extension of this, that he was a diligent attendant on the meetings of the Royal, the Geological, and other Societies, and took a keen interest in their proceedings. Occasional excursions to the country appear to have been his only recreation. These afforded him an opportunity of prosecuting geology, which was a favourite study, and, during the last twelve years of his life, enabled him to gratify the love for angling with which Sir H. Davy had infected him.

His reluctance, or rather positive refusal, to admit even friends to his laboratory, has already been referred to. Plato is said to have written above the door of his study, 'Let no one who is not a mathematician enter.' Had Wollaston placed an inscription, or rather a proscription, above the

door of his laboratory, it would have been still more brief and comprehensive. 'Let NO one enter.' It is related that a gentleman of his acquaintance, having been left by the servant to ramble from one room to another till he should be ready to see him, penetrated into the laboratory. The doctor, on coming in, discovered the intrusion; but not suffering himself to express all he felt on the occasion, took his friend by the arm, and having led him to the most sacred spot in the room, said—'Mr. P., do you see that furnace?' 'I do.' 'Then make a profound bow to it, for as this is the first time, it will also be the last time, of your seeing it.'

This hermetically-sealed laboratory is known to have been of small dimensions. It did not require to be large, for Wollaston's researches were systematically prosecuted on a scale of nearly microscopic minuteness. He was celebrated for the almost atomic quantities of matter on which he wrought to as much good purpose as other men on hundreds of grains. His demonstration of the identity of columbium and tantalum was founded upon the examination of a very few grains of two rare minerals. His detection of titanium in the iron slags was effected on equally small quantities.

Dr. Paris mentions, in his life of Davy, that a foreign philosopher once called upon Dr. Wollaston with letters of introduction, and expressed an anxious desire to see his laboratory. 'Certainly,' he replied, and immediately produced a small tray containing some glass tubes, a blowpipe, two or three watch-glasses, a slip of platina, and a few test-tubes. It is added by the same gentleman, that Wollaston appeared to take great delight in showing by what small means he could produce great results. Shortly after he had inspected the grand galvanic battery constructed

by Mr. Children, and had witnessed some of those brilliant phenomena of combustion which its powers produced, he accidentally met a brother chemist in the street. Seizing his button (his constant habit when speaking on any subject of interest), he led him into a secluded corner, when, taking from his waistcoat-pocket a tailor's thimble, which contained a galvanic arrangement, and pouring into it the contents of a small vial, he instantly heated a platina wire to a white heat.

Wollaston was fond of amassing money: there have not, indeed, been wanting accusations to the effect, that if he had sought less after wealth, he would have done more for science. How far these charges are true, we have no means of judging, as it does not appear from the published accounts, in what exact way he made his money. That it was chiefly by the platina process is certain, but whether he engaged in the manufacture himself, or only superintended it, we do not know. On this point we would only remark, that there is something, to say the least of it, very partial and unfair in the way in which obloquy is cast upon men of science, if they appropriate to themselves some of the wealth which their discoveries procure for others. If a successful naval or military hero is lavishly pensioned out of the public purse, no one complains. It is not thought strange that a great painter or sculptor, whilst he justly declares his productions are worth untold gold, should nevertheless demand a modicum of coin from his admirers. Neither is the poet or musician blamed who sells his works to the highest bidder. But if a chemist, for whom there are few pensions and no peerages, think to help out a scanty or insufficient income by manufacturing gunpowder like Davy, or magnesia like Henry, or malleable platina like Wollaston, or guano like Liebig, the detractors assail him

at once. He has lowered the dignity of his science, and, it would seem, should starve, rather than degrade his vocation. That vocation, so far, at least, as the practical fruits of his own labours are concerned, is to be a kind of jackal, to start game which others are to follow, a beagle, to hunt down prey which others may devour. Surely there is but scanty justice here, and some forgetfulness of a sacred text, 'Thou shalt not muzzle the mouth of the ox that treadeth out the corn.'

We are no advocates of a sordid spirit in men of science, neither do we lament that Government is less liberal to them in this than in other countries. When we look at the roll of our illustrious men, we see little reason to regret that they have not the grants which France, Germany, and Russia so freely bestow. Neither system is perfect, and our own, with all its faults, works well. But private enterprise must manifestly supplement the deficiencies of Government aid. It is therefore unfair to blame an unpensioned, unplaced chemist like Wollaston, if he secure an income by his independent labour. To manufacture platina may be, in the eyes of the world, a less dignified occupation than practising medicine, but it left the man of science much more leisure for his studies than physic would have done, and paid him a great deal better.

We will not, however, take it on us to affirm that Wollaston might not have been content with less than £30,000. Perhaps, and probably he might have been, though we know too little of his circumstances to be able to judge exactly on that point. That he did not selfishly hoard his money may be gathered from the following anecdote, which is declared to be authentic. Having been applied to by a gentleman, who was involved by unexpected difficulties, to procure him some Government situation, Dr.

Wollaston's reply was,—'I have lived to sixty without asking a single favour from men in office, and it is not after that age that I shall be induced to do so, even were it to serve a brother. If the enclosed can be of use to you in your present difficulties, pray accept it, for it is much at your service.' The enclosed was a cheque for ten thousand pounds.

In attempting further to illustrate Wollaston's character, we must have recourse to the device so common with biographers, of comparing him with some of those who were engaged in the same pursuits as himself. A natural and admirable occasion for doing so, such as Plutarch would have delighted in, is afforded by the fact that Wollaston and Davy were contemporaries and friends. It is difficult to imagine a greater contrast than that between the eager, imaginative poet-chemist, on the one hand, and the austere, unimpassioned, monk-philosopher on the other. Davy was a man of sanguine, enthusiastic temperament, overflowing with life and animation; Wollaston's nature was as still and unmoved as the bosom of a lake hidden from the wind in the recesses of a cavern. The former was a spoiled child of nature and of fortune, and greedy of applause. He delighted in the approving smiles of ladies, and was flattered by the notice of the great. It was a source of pain to him that he was not of good family. Wollaston was a disappointed man. He begged one boon from his brethren, the physicianship of an hospital; when that was refused him, he shut himself up in his laboratory, and rejoiced, when sixty years old, that he would not ask a favour, even for a brother. He was indifferent to the notice of all but scientific persons, and avoided every occasion of attracting popular attention.

Their characters as philosophers were as different as their

tastes and habits as men. Davy had far greater originating power, boldness of speculation, and faculty of generalization; and he showed great skill in realizing his ideas. Wollaston excelled Davy in extent of scientific accomplishment, in minute accuracy of observation, and in closeness of reasoning. He wrought out his conceptions with singular ingenuity, and brought the utmost mechanical experience and dexterity to the solution of difficult questions. Both were good artists and manipulators, but Wollaston was much the better of the two. Davy was very ingenious in devising, but reckless and inexperienced in constructing. Wollaston excelled him in ingenuity, and, moreover, was a first-rate workman.

The mode in which they reached their discoveries was as dissimilar as the subjects which they selected. Davy considered the faintest analogy worth pursuing. Possibilities were with him probabilities; probabilities, truths. Wollaston's idea of a truth was not so much something proved true, but something which could not be proved not to be true. His most positive yes was often a *not* no, rather than a hearty yea and amen. When Davy took up an inquiry, it was with the highest hopes and visions of success. If he gained his end, he was greatly elated; if he failed, he was correspondingly depressed. Wollaston set about a scientific undertaking more as if it were a matter of duty than an occupation which by its result could possibly give him pain or pleasure. His pulse probably never quickened or slackened a beat in consequence of success or failure. When Davy discovered potassium, his delight and agitation were so great, that he enrolled the fact in his notebook in an almost illegible scrawl. Wollaston would have written the announcement in his roundest hand. With Davy, the end of the inquiry was the great object; the shortest way

by which it could be reached was the best. The means by which it was arrived at, were in themselves indifferent. He hastened impetuously to reach the goal. For Wollaston, the journey had interest, whatever might be its conclusion. He hated to make a false or doubtful move, though it might advance him towards his ultimate object. Each stage of the undertaking was, for the time, the entire subject of concern. He travelled leisurely along, breaking new ground with the utmost caution, fastidious about every step of the journey. A sufficient pathway would not content him, though no one might follow his steps. He must stop, and make it a perfect road. The one philosopher was like the stag-hound running down the game his keen eye got sight of, by speed of foot and nimbleness of limb, or missing it altogether. The other resembled the blood-hound following leisurely on the trail of his prey; slow, comparatively, in his movements, and with eyes fixed upon the ground, but certain never to quit the chase, or to make one false step till he was up with his victim. Davy's genius was like the burning thunderbolt whose forces he did so much to explain. Attracted only by towering and lofty things, it smote down from the zenith, prostrating maiden citadels, and scattering in dust, or dissipating in fiery drops, whatsoever opposed it. Wollaston's genius was like the light, whose laws he so much loved to study. It was not, however, the blazing light of day that it resembled, but the still moonlight, as ready with clear but cold radiance to shine in on a solitary obscure chamber, as able to illuminate with its unburning beams, every dark and stately hall of the closed fortresses where Nature keeps her secrets.

In their habits of laboratory working and manipulation, Davy and Wollaston have been compared to the painters Michael Angelo and Teniers; the former, reckless, im-

petuous, and turbulent in his mode of producing results; the latter, minute, microscopic, precise, and accurate, even in the smallest details. The comparison is just, so far, but it either elevates Davy too high, or degrades Wollaston too low. Davy devising his safety-lamp, after a few rapidly performed experiments, may be the Michael Angelo, contrasted with Wollaston, the Teniers, slowly perfecting a process for drawing out a capillary gold wire. But Wollaston, solving by means of a little telescope of his own adaptation, the problem of the existence of an atmosphere round the sun, contrasted with Davy discovering potassium by means of a gigantic voltaic battery, and every other aid and appliance to boot, must be called (as an artist friend suggests) at least a Correggio, whilst the latter is styled rather a Titian than a Michael Angelo. Davy and Wollaston were men of most marked individuality of character, and giants both. The youthful student will do well who accepts the guidance of either. He will do better, if, like Faraday, he unite the excellencies of both.

To these attempts to bring out Wollaston's character by contrast with that of his great contemporary, we would add a word or two concerning his likeness in disposition to another of our distinguished men of science. Those who are acquainted with the life of the Honourable Henry Cavendish, will acknowledge that he and Wollaston resembled each other greatly. In both there was the same austerity, taciturnity, and reserve; the same extreme caution in drawing conclusions, and exact precision in stating them; the same catholicity of tastes as regarded their philosophical pursuits; the same relish for scientific society, and dislike to any other; the same indifference to applause; the same frugal habits; the same candour and justice towards other men of science; and the same strong love of truth and per-

fect integrity. And as in life they were alike, so in death they were not divided. The closing moments of the one were marked by the same kind of calm courage and serenity which distinguished the death-bed of the other. Cavendish and Wollaston might in truth have been twin-brothers.

In contrasting Wollaston with Davy, and in comparing him with Cavendish, we have not willingly overstated matters. But all such attempts partake more or less of rhetorical artifice, and convey at best but a partial and imperfect idea of the character of any individual. No man is exactly the opposite or exactly the image of another. If his name be worth preserving at all, his individuality must be marked, and should be susceptible of definition and demonstration. It seems to us that three predominant qualities determined the scope of Wollaston's genius. The statement of these will perhaps in some degree explain the comparatively slight impression which he has made on science, and the partial oblivion into which his name has already fallen.

We remark first, that, in common with all great observers in physics, he possessed a keen intellect, a well balanced judgment, a most retentive memory, rapidity and readiness in discerning analogies, great power of analysis and also of generalization, perseverance in working out ideas once started, and practical skill in effecting their realization.

To hold in check these estimable qualities, there existed in the first place a quite inordinate caution, which never permitted them to range freely over the domains of science. Wollaston's caution was of a peculiar kind. It was not the wariness of timidity or self-distrust. He was in all respects a courageous man, and had much more self-reliance than Davy. The boldness of a speculation would not have deterred him from entertaining it. It would, in truth, have

been neither a recommendation nor an objection to any suggestion. Fearlessness or timidity, as evinced in a hypothesis or theory, were qualities intangible to science, which was only concerned with the question, was the speculation true, or was it not?

It was untruth that Wollaston so greatly dreaded; and the fear of it made him prone to under-estimate the positive worth of any fact. An inquiry thus became for him a very tedious and protracted affair. It was not sufficient that a fact, perhaps quite incidental to the main object, and what other men would have called trivial, was true enough for the use he had to make of it. It must be true enough for every purpose it could be applied to: in a word, positively and absolutely true. Wollaston was thus like a man crossing a river by casting in stepping-stones, but who would not be content, that, with here and there a pretty long leap, and now and then a plash and a wetting, he should get across. He must stop and square and set each stone, before he stepped on to the next, and so measure his way to the other side. Yet the stones were no more to him than to other travellers. To cross the river was his object as well as theirs. The stepping-stones were only the means to that. But they were doubtful and uncertain means, if carelessly arranged. Many would reach the opposite side in safety, but a single pilgrim might be washed away and drowned. Wollaston made a pathway safe even for the blind.

Davy, when he discovered potassium, argued somewhat thus: It is probable for several, or (as he would say) for many reasons, that potash and soda are the oxides of metals. It is also probable that electricity, which can decompose so many things, will be able to decompose them. He tried if it would, and discovered some dozen new metals. Wollas-

ton would have said, It is possible that the alkalies contain metals, and possible also that electricity could separate them. But at that point he would have stopped to array the probabilities against both ideas proving true ; and these would have appeared so strong that he would never have gone further.

All discoverers, with the exception of the very highest, such as Newton, take a great deal for granted. They advance not by steps, but by strides, and often gain their ends in strange ways. The new country in which they land themselves and their brethren, is reached by some bold attempt which is soon stigmatized as illegitimate and unworthy. The new country, however, is there for all that, and more legitimate and worthy methods of approach are soon discovered. We have Liebig for example, in our own day, accused of assuming doctrines that he cannot prove ; and of giving us hypotheses as thoroughly established generalizations. Now and then he is provoked to return some indignant rejoinder to the bitter denunciations of his angry critics. But they make no abiding impression on the eager German, who replies with fresh assumptions and new hypotheses, more aggravating than before. His successors will doubtless weed out of his system as useless many things which he counts as essential to it, and establish as only partially just, much that he believes to be absolutely true. But if Liebig had stopped like Wollaston to render each step in his progress incontrovertible, organic chemistry would be infinitely less advanced than it is at the present day.

Had Wollaston been a man of as grand and as fine intellect as Newton, his caution would not have prevented him being a great discoverer ; but with faculties much more limited than his, he had caution equally great. Accord-

ingly, although he had the start of Davy in electricity, and knew that science thoroughly, he allowed the latter to carry off the greater number of the trophies in galvanic discovery. He detected for himself the law of combination in multiple proportion, and might have extended it into such a scheme as Dalton embodied in his atomic hypothesis. Wollaston was infinitely better qualified than Dalton to investigate by experiment, laws of combination. But he stopped with the discovery of the one law, and did not even publish that, till Dalton had made it known along with several others.

But characteristic as caution was of Wollaston, it may be questioned whether it was more strongly marked in him than in many other philosophers. Black, and still more Cavendish, were as cautious as he was. We must look farther, before we can sufficiently account for the apparently small amount of fruit which his life of scientific labour yielded.

We would indicate as the second feature in Wollaston's mind which prevented his effecting greater achievements, the versatility of his tastes. There was scarcely a science which he had not studied and was not competent to extend. His Cambridge education gave him a taste for mathematics, and the mathematico-physical sciences. From his father he inherited a fondness for astronomy, and by him he was probably initiated into its mysteries from his earliest years. No man can be long an astronomer without feeling it necessary to study geology: Wollaston accordingly became a geologist. Neither will any one make much use of telescopes without becoming anxious to understand and to improve their construction: all astronomers, accordingly, are students of optics. Wollaston was a most diligent one. None of these sciences, however, will support their votaries: our philosopher accordingly studied medicine. This

introduced him to anatomy, physiology, pathology, botany, and chemistry, on each of which he published papers.

Davy had a most imperfect acquaintance with all the sciences, except chemistry and electricity. Wollaston knew them all, and worked at them by turns. A list of some of his papers which we have not commented upon will show how impartially he distributed his attention. The Bakerian lecture for 1803: 'Observations of the quantity of horizontal refraction; with a method of measuring the dip at sea.' The Bakerian lecture for 1806: 'On the force of percussion.' The Croonian lecture for 1810: 'On muscular motion, sea-sickness, and carriage exercise.' The Bakerian lecture for 1813: 'On the elementary particles of certain crystals.' 'On a method of freezing at a distance.' 'On a method of drawing extremely fine wires.' 'On a periscopic camera obscura and microscope.' 'On a method of cutting rock crystal for micrometers.' 'On gouty concretions.' 'On the concentric adjustment of a triple object-glass,' etc. etc. The reader will add to these, those named or discussed in our article already.

Davy was obliged to confine himself to the two sciences he knew, and in consequence, greatly extended them. Wollaston had the 'open sesame' to them all, and the result was, that he did a little for every one. He who divides his fortune into a number of small bequests, and leaves one to each of those who have a claim on him, is thanked for the time, but speedily forgotten. But when a man gives his all to a single great object, it embalms his memory. Wollaston has passed from men's notice. Davy is immortal.

There remains, however, a third characteristic to be noticed before we can understand all that biassed Wollaston, and turned his thoughts away from great scientific actions. We allude to his wonderful inventiveness and mechanical

ingenuity. We call it wonderful, because, with the exception of James Watt, Hooke, and a very few others, Wollaston surpassed all his scientific countrymen in this respect, and there are not many foreign natural philosophers who could be placed above him. Without entering into any detailed proof of this, we only remind the reader that he was the inventor of the reflecting goniometer, the camera lucida, the dip sector, the cryophorus ; of a micrometer, of various improvements on the microscope, on the common eye-glass, on the camera obscura, and of one most important one on the telescope ; of the method of rendering platina malleable, of a method of drawing extremely fine wires, of a method of comparing the light of the sun with that of the fixed stars, and of many others which we cannot stop to mention. In addition to these special inventions, his papers are filled with descriptions of the most ingenious and original contrivances for securing the ends he had in view. When he became an angler, he astonished his friends by many curious devices for overcoming difficulties in the new art he had taken up.

It must have come within the observation of most persons, that very ingenious mechanical contrivers find the greatest pleasure in giving birth to inventions, and, where no other and higher taste divides their inclinations, and no pressing duty occupies their time, often devote themselves entirely to the gratification of their talent. It is most natural that they should do so. There are few intellectual pleasures greater than that of being creators, even to the extent that man may be one. The feeling of exultation with which the poet, the painter, or the musician, rejoices over the offspring of his genius, is shared, though in a lower degree, by the inventor, whose new instrument or method is as much a creation, the embodiment and monument of

an idea or ideas, as the poem, or the picture, or the oratorio. In many men, ingenuity goes no further than devising. They are not craftsmen, to execute their plans ; and to give them to workmen would involve too costly a gratification of their wishes. But Wollaston was an excellent workman ; his hand was as ready to construct as his brain to invent ; and they went together. There was thus a twofold temptation to gratify his inventive powers ; and he did gratify them to the utmost : but time so spent was often little better than thrown away. We rejoice that he invented a reflecting goniometer, and supplied an achromatic object-glass for the telescope, and we do not grudge the camera lucida ; but as for the not very important improvement of spectacles, microscopes, and cameræ obscuræ, they might safely have been left to be made by a duller man, when it appeared they were wanted. It was putting Pegasus in the yoke, or setting Samson to grind at the mill, to waste Wollaston's energies on such work. His case should be a warning to young scientific men who have a great mechanical turn, to take care that it does not warp them aside from higher objects, and convert them into mere instrument-makers. When we think how many inventions are only works of supererogation, no better than Rob Roy's self-acting pistol, which was to protect the entrance into a leather purse ; or useless toys, like the recent Eureka machine, for making nonsense Latin hexameters, or of the most circumscribed application, like patent needle-threaders ; we cannot but wish that each inventor would pause, and ask whether there is, or will be any need or demand for what he is about to devise, before he proceeds to execute his project. Many of Wollaston's inventions are now forgotten or superseded.

The restraint and distraction of faculty which these three

influences occasioned, were fatal to Wollaston's being a distinguished or systematic discoverer. His inordinate intellectual caution kept him from giving to the world any great generalization. Had he attempted one, he would have spent a lifetime in establishing it to his own satisfaction. His acquaintance with most of the physical sciences induced him, instead of dedicating his life to the establishment of some one great theory in a single branch of knowledge, to pursue many inquiries in each; these were sufficiently limited in scope to be brought to a conclusion, satisfactory even to his fastidious, sceptical spirit, in a reasonable time. His mechanical ingenuity constantly tempted him to improve some one of the thousand instruments of physical science which are not perfect.

He must nevertheless be counted great, on the ground of the multitude of single works which he executed so ably. He will stand in the second rank of great physical philosophers, along with Black and Cavendish, Davy and Dalton.

The portraits of Wollaston represent him as a grave, silent, meditative man: one who would excite much sincere respect, but little enthusiastic affection, among those who knew him. He led a solitary life, and was never married.

His senses were peculiarly acute—a valuable possession to a physical philosopher. Some, indeed, have dwelt upon the acuteness of Wollaston's senses as the source of his greatness as an inventor and discoverer. Others have indignantly affirmed that it was wronging a great philosopher to ascribe his triumphs over nature, merely to his having had a sharp eye and nimble fingers. The dispute seems a needless and a foolish one. That Wollaston had very acute bodily senses, has been certified to us by himself,

and by those who were his associates. But if any one think that the mere possession of these will make a man a Wollaston, let him only consider that there is not a Red Indian or an Esquimaux who can distinguish a white hare from the white snow around it, who does not at least equal, if not far surpass, the philosopher in acuteness of bodily senses.

On the other hand, it would be in the highest degree unwise to despise the gifts of sensitive bodily organs, and to leave out of consideration the influence of the physical element in determining the character of men. Soul and body must be present in certain though varying proportions, to suit us for our special vocations; and the elements must be as kindly, though differently mixed, to give the world assurance of a physical philosopher as of a poet or a statesman. Wollaston, like most of his distinguished fellow-men, owed a great deal to his body, but a great deal more to his soul.

From what has been already stated, it will be manifest that our philosopher was not what most people would term an amiable person. He was, however, a just and most honourable man; candid, open, and free from envy. Of this, many proofs might be given. We have already seen that he freely lent his influence to secure Sir H. Davy the chair of the Royal Society. His papers, also, afford incidentally many evidences of his candour. In the one on the finite extent of the atmosphere, he mentions, that after making his own observations on the transit of Venus over the sun's disk, he discovered that results equally accurate had already been obtained by M. Vidal of Montpellier, to whom, accordingly, he assigns the priority. In his essay on the forms of the elementary particles of certain crystals, he points out that he had been anticipated by Dr. Hooke. He

states, as a reason for publishing his paper on super and sub-acid salts, that he wished to furnish Dr. Dalton with a better means of proving the truth of his doctrine of combination in multiple proportions than the latter's analysis of certain gases had supplied. He had occasion to point out that the chemist Chenevix had committed a great blunder in reference to the properties of the metal palladium: he did it in the most delicate and courteous way.

Altogether, the combination of reserve with perfect straightforwardness; the relish for acquiring money, with the generosity in parting with it when it could be worthily bestowed; the clear intellect, the self-reliance, the aversion to interference or intrusion on the part of strangers; the impartial justice to rivals, and the business-like method of all his habits, seem to us pre-eminently to mark out Wollaston as, *par excellence*, The *English* Philosopher.

LIFE AND DISCOVERIES OF DALTON.[1]

THE decease of Dalton, the greatest of English chemists, and one of the most distinguished cultivators of general physics, has naturally awakened a desire, on the part of many, to know something concerning his scientific discoveries and personal history. No satisfactory account has been hitherto published either of the former or the latter. We trust that the following sketch will go some way towards supplying this deficiency.[2]

John Dalton was born at Eaglesfield, near Cockermouth, in Cumberland, on the 5th of September 1766. His father, Joseph Dalton, was originally a person of no property, but after the death of an elder brother, he became possessed of a small copyhold estate, which he farmed with the assistance of his sons. He had six children, of whom only three survived to maturity—Jonathan, John, the subject of this

[1] (1.) *Meteorological Observations and Essays.* By John Dalton, D.C.L., F.R.S. First Edition, 1793. Second Edition, 1834.

(2.) *A New System of Chemical Philosophy.* By John Dalton. Part I. 1808. Part II. 1810. Vol. II. 1827.

(3.) *Memoirs of the Literary and Philosophical Society of Manchester from* 1793 to 1836.

[2] Since this was written, a Memoir of Dalton has appeared, under the auspices of the Cavendish Society, from the pen of Dr. Henry. In the preface, he speaks of this notice as 'an elaborate and well-conceived article by Dr. G. Wilson, the accomplished biographer of Cavendish,—beyond comparison the ablest and justest appreciation that has yet appeared of Dalton's philosophical character and discoveries.'—EDITOR.

article, and Mary. The first-named of these obtained the estate on the decease of his father, and retained it till his own death, in or near the year 1835, when it became the property of John Dalton.

Joseph, the father, though straitened in circumstances, strove to give his family the best education within his means, and John attended a school conducted by a member of the Society of Friends, named John Fletcher, until he had attained his twelfth year. We have no means of knowing anything concerning the nature or amount of the instructions which he received at this school (the only one he ever attended); but he is said to have made 'very considerable progress in knowledge,' and he always spoke with respect of his early preceptor. That he did make such progress, and that he gave early proof of rare energy and natural capability, we may gather from the fact, that at the age of twelve or thirteen, he commenced a school in his native village, and persevered in teaching during two winters.

So modest, unassuming, and conscientious a man, as Dalton proved himself in after-life to be, must have been conscious, even at that early age, of the possession, both of knowledge, and of the power to impart it, or he would not have committed himself to so difficult a task. How he prospered in it we are not told, but probably not greatly, for we learn that his vacant time was occupied in assisting his father upon his farm; and he is said to have taken part in the labour of altering the farm-house. He manifested a strong tendency towards mathematical pursuits when very young, and had some assistance in the prosecution of his taste in that respect from a gentleman named Robinson, who, along with his wife, an accomplished woman, directed the studies of the young philosopher.

In 1781, at the age of fifteen, Dalton removed to Kendal, where his cousin, named George Bewley, then resided, as the teacher of a boarding-school, with whom the brother of Dalton had lived as an assistant. Dalton succeeded his brother in this office, and resided in Kendal till 1792, actively engaged in learning and teaching mathematics and the physical sciences. During his residence in that town, he attracted the attention of Mr. Gough, a blind gentleman, who, in spite of his misfortune, was devoted to the study of physics and natural history. Mr. Gough had an excellent library and some apparatus, which he placed freely at the disposal of Dalton, who soon became his assistant and companion. The service required was of a light and pleasant description, and the blind philosopher, who was possessed of excellent natural abilities, and had obtained a liberal education, appears to have acted the kindest part towards Dalton, who, in return, was never weary of expressing his sense of obligation to his benefactor. When Dalton published his Meteorological Essays, in 1793, he said, in reference to Mr. Gough—'If there be anything new, and of importance to science, embraced in this work, it is owing, in great part, to my having had the advantage of his instructions and example in philosophical examination.' And although we may believe that Dalton's modesty led him somewhat to over-estimate his obligation to Mr. Gough, there can be no doubt that a person whose early education had been comparatively so neglected, must have derived the greatest benefit from intercourse with such a person as the lattter is described to have been. After his death, and so late as 1834, Dalton spoke of him as a prodigy in scientific attainments, considering the disadvantages under which he laboured, and added—

'There are few branches of science in which he did not

either excel, or of which he had not a competent knowledge. Astronomy, optics, pneumatics, chemistry, natural history in general, and botany in particular, may be mentioned.

'For about eight years,' continues Dalton, 'during my residence in Kendal, we were intimately acquainted. Mr. Gough was as much gratified in imparting his stores of science as I was in receiving them; my use to him was chiefly in reading, writing, and making calculations and diagrams, and in participating with him in the pleasure resulting from successful investigations; but as Mr. Gough was above receiving any pecuniary recompense, the balance of advantage was greatly in my favour, and I am glad of having this opportunity of acknowledging it.'

From the year 1784 to 1794, we find Dalton contributing largely to two works, of some celebrity in their day, but now little remembered, entitled, *The Gentleman's and the Lady's Diary*. In 1788, he commenced his meteorological observations, which led, directly or indirectly, to all his great discoveries, and were continued till the day before his death. In 1793, he published his first work, *Meteorological Observations and Essays*, to which more particular reference will be made hereafter.

Some time previous to the appearance of that publication, Dalton had thought of qualifying himself to practise either as a physician or a lawyer, and corresponded with a friend in London on the subject. But his views were changed in consequence of the receipt of a letter, by his friend Mr. Gough, from Dr. Barnes, making inquiry for a gentleman to fill the situation of Professor of Mathematics and Natural Philosophy, in the new college, Mosley Street, Manchester. Dalton's offer to undertake the duties was accepted, and he removed, in 1793, to Manchester, where he spent the remainder of his days.

The year after settling in that town, Dalton joined a society, which had been established for some time, under the title of the 'Manchester Literary and Philosophical Society.' To the Transactions of this body — the most celebrated of all our provincial scientific associations—he contributed a series of papers, containing the results of original researches of the highest value. These, along with a few others on kindred subjects, have conferred on the society's periodical publications, best known as the *Manchester Memoirs*, a celebrity which has extended beyond the nations of Europe. Dalton resided for about six years within the Mosley Street institution, and continued to officiate there till the college was removed to York, in 1799, when he began to teach mathematics and natural philosophy privately, at the charge, it is said, of eighteenpence an hour.

In this humble occupation he was engaged, when, in 1804, he unfolded the laws which he had discovered to regulate the proportions in which substances combine chemically with each other, along with the hypothesis, by means of which he accounted for their existence, and expounded them. The laws and the hypothesis are generally, though erroneously, taken together, and included under the single title of his 'Atomic Theory.'

Here, then, we may, for a while, arrest the course of purely biographical detail, and, leaving Dalton teaching his mathematics at eighteenpence an hour, turn to the consideration of his scientific discoveries.

We need scarcely say that it will not be possible to offer more than the briefest sketch of these; and that even this will be out of our power, unless we confine ourselves to the chief points in relation to them. We shall select, therefore, his 'Atomic Theory' as the main subject of

illustration, and consider his other discoveries as they stand related to it. Great unity, and the impress of intellectual consistency, are stamped on all Dalton's labours. With few exceptions, they bear closely and directly upon each other, and on the atomic hypothesis of combining proportion, to which they ultimately led, and round which they naturally group themselves. The method which we shall follow, will serve, accordingly, both to bring out the nature and value of his discoveries in science, and to indicate the train of speculation and inquiry by which he was conducted to them.

As the first step towards this, we have to consider the laws of proportional combination, which are universally received as true by chemists. They are four in number, and refer to combination by *weight;* the laws of combination by *volume* being excluded from our present inquiry. Three of them were discovered by Dalton; all of them were brought into new prominence by his labours; and his atomic theory, or rather hypothesis, as it should be called, is an endeavour to explain them, by assuming a peculiar ultimate constitution of matter, which absolutely necessitates their existence. These laws are based upon one, deeper and more fundamental than themselves, which is assumed in their enunciation, and is to the following effect: —*The same compound consists invariably of the same components.* Water, for example, always consists of oxygen and hydrogen; common salt, of chlorine and sodium; vermilion, of sulphur and mercury. Exceptions to this law were at one time thought to exist, in the case of certain minerals and native gems, such as garnet, which seemed to exhibit constant physical characters, and yet to vary in their constituent ingredients. But Mitscherlich's discovery of Isomorphism not only solved the difficulty attending the

consideration of these, but in the end supplied new confirmation of the law which at first it seemed to contradict. This then premised, we may enter at once on the consideration of the following laws :—

The first of these is generally named the law of *Definite* proportion, but should rather be called the law of *Constant Proportion.* It teaches, that the elements which form a chemical compound are always united in it in the *same* proportion by weight. Water not only consists invariably of oxygen and hydrogen, but the weight of oxygen present is always eight times greater than that of hydrogen. Whether we obtain it from lake, or river, or sea, or glacier, or iceberg ; from rain, or snow, or hail, or dew ; from the structures of plants or the bodies of animals ; whether it has been formed ages ago by the hand of nature, or is produced on the instant by mingling together its elements in the most random way, the ratio of its components is immutably the same : eight-ninths of its weight are always oxygen, and the remaining ninth, hydrogen. It is the same with every compound. Common salt always contains 35 parts of chlorine to 22 of sodium ; marble, 22 of carbonic acid to 28 of lime ; vermilion, 16 of sulphur to 101 of mercury. In virtue of this law, a number can be found for every body, simple or compound, expressing the ratio in which (or in a multiple or submultiple of which) it combines with every other. Any series of numbers may be taken to represent these combining ratios, provided the due proportion is maintained among them, so that the number for oxygen shall be eight times greater than that for hydrogen, that for nitrogen fourteen times greater, that for sulphur sixteen times, that for iron twenty-seven times, and so on, according to the relations which analysis brings out. Different scales of combining numbers are in use among chemists ;

but the only one we need consider is that which makes hydrogen 1, and counts from it upwards. The numbers in this scale are all small, and do not, in the majority of cases, go beyond two integers.[1]

It must not be forgotten that such tables represent relative, not absolute weights. Of the smallest possible quantity of oxygen which can combine with the smallest possible quantity of hydrogen, we know nothing; all that we are certain of is, that it is eight times greater than that of hydrogen, whatever that be. None of the numbers taken singly has any absolute value: the 16, for example, which, in tables of the kind we are discussing, stands against sulphur, does not represent 16 grains, 16 millionths of a grain, or any other absolute quantity; its value appears only when it is taken in connexion with the number attached to hydrogen, to which the quite arbitrary value of 1 has been given. We may give any value we please to any one of the elementary bodies we choose to fix upon for a commencement, and call it 1, 10, 100, $\frac{1}{2}$, $\frac{1}{4}$, or any other integer or fraction; but here our liberty ceases. The relation between the numbers is absolute, though their individual value is not; and from the settled figure we must count upwards or downwards, or both ways, so as to maintain inviolate the relative values throughout the series.

The law we are discussing, as we have already stated, is generally called that of *definite* proportion, but, as we think, erroneously; for it asserts something more than that the

[1] In conformity with the universal practice of chemists, in illustrating the laws of combined proportion, we have here, and elsewhere throughout this paper, employed round numbers, cutting off the decimal fractions, by which the exact combining proportions exceed or fall short of these. The equivalent of oxygen, for example, is not 8, but 8.01; that of nitrogen, not 14, but 14.06; and so on with many others. The equivalents of a few of the elementary bodies are round numbers: carbon is 6; calcium, 20: the greater number are not.

proportion in which the elements of a compound unite is *definite;* it affirms, also, that it is *constant*, or always the same. The elements of a compound *must* be united in definite proportion. A definite weight of water, for example, must consist of a definite weight of hydrogen and of oxygen; but the proportion of these elements might be quite variable, so that one specimen of water should be found to contain 1 hydrogen to 8 oxygen; another, 8 hydrogen to 1 oxygen; a third, a moiety of either ingredient; and so on, *ad infinitum.*

The native garnet to which reference has already been made, is always a definite compound; but the proportion of its ingredients varies within wide limits, so that while one specimen contains 27 per cent. of a certain constituent *alumina*, another does not contain 1 per cent. The alum of the dyer may in the same way contain a proportion of peroxide of iron, varying in different specimens from 1 to 90 per cent.; and differences in the ratio of ingredients as great as these occur in all the combinations of what are called isomorphous bodies. These garnets and alums, however, are in reality mixtures in variable proportions of quite constant compounds, and offer no exception to the law we are discussing, but they illustrate what is manifestly quite possible, that constancy in physical character, and constancy in the nature of the constituent ingredients, might co-exist with inconstancy in the *proportion* of the latter. Now Dalton's first law affirms, in contradiction to this possibility, that the proportion of elements in a compound is in every case as constant as their nature; a truth which the title, 'Law of *definite* proportion,' does not bring out, whilst that of *constant* proportion not only does, but in addition includes all that the former expresses; for a *constant* proportion must of necessity be a *definite* one also.

For these reasons we press upon the reader the propriety of avoiding the singular and almost unaccountable confusion which exists in many of our best works in the use of the word *definite*, as equivalent to *constant*, and name the law—that of constant proportion.

This law applies to all bodies, organic and inorganic, native and artificial, so that in the light of it our earth, with its atmosphere, may be considered as the sum or complement of an almost infinite number of compounds adjusted by weight, and told to the tale ; and in a sense as mathematically true as it is poetically sublime, we may understand the declaration of an inspired writer, that God has 'weighed the mountains in scales and the hills in a balance.'

The law of constant proportion was known before Dalton's time, and had been distinctly announced by several chemists in different countries towards the close of last century. We can scarcely doubt that it had been fully apprehended, in many quarters, before it was specially proclaimed. Every chemist who undertook the analysis of a substance must have blindly or intelligently taken for granted that it would prove *definite* in composition ; and most of them, we may readily believe, connected with this a more or less clearly discerned expectation that it would prove *constant* in composition also. This length, certainly, Bergmann the Swede, our own Cavendish, Lavoisier, and many others, had reached, in their observations and speculations on the combinations of bodies ; but it was made the subject of special demonstration by two German chemists, Wenzel and Richter, and by a French chemist, Proust, who published their respective works between the years 1777 and 1792. The views of the German chemists will come better under our notice when discussing the third law of combin-

ing proportion; those of Proust deserve more particular mention here, as they were published in consequence of a discussion carried on between him and the celebrated French chemist, Berthollet, as to the existence of such a law as the one we are considering. Berthollet asserted that the number of compounds which any two elements can form with each other is quite unlimited, and that constancy of physical characters, such as specific gravity, colour, taste, etc., is no sign of constancy in chemical composition. Proust affirmed, on the other hand, that the number of compounds formed by two elements, such as iron and oxygen, is always limited, and often very small; and that so long as the physical characters remain unchanged, the chemical composition is equally invariable. The evidence adduced by him was so ample and incontrovertible, that the discussion ended in satisfying every chemist of the truth of his views.

The second law of combining proportion is related to the circumstance, that the same elements, in almost every case, combine in more than one proportion to constitute several compounds. Even the beginner will be prepared for this, if he is aware that the chemist has, in the meanwhile, reduced all kinds of matter to some fifty-six primary ones, and has the whole world to account for out of these. This law is named that of *Multiple Proportion*, and enforces the remarkable truth, that when one body combines with another in several proportions, the higher ones are multiples of the first or lowest. Oxygen and hydrogen, for example, which in water are united in the ratio of eight of the former to one of the latter, unite to form a second compound, named the peroxide of hydrogen, in which the oxygen is to the hydrogen as 16 to 1; or, the hydrogen remaining the same, there is exactly twice as much oxygen as in water.

There are two compounds of hydrogen and carbon remarkable as being the bodies which suggested this law to Dalton. In the one of these (*olefiant gas*), there are six parts, by weight, of carbon, to one of hydrogen ; in the other (*marsh gas*, or *fire-damp*) there are six parts of carbon to two of hydrogen ; or, the weight of carbon being the same in both, there is exactly twice as much hydrogen in the first as in the second. One of the most remarkable examples of this law occurs in the compounds of nitrogen and oxygen, which are five in number. The proportion of nitrogen is the same in all, and may be represented by the number 14, while that of the oxygen, which in the lowest may be expressed by 8, in the second is 16, or twice 8 ; in the third, 24, or three times 8 ; in the fourth, 32, or four times 8 ; and in the fifth, 40, or five times 8 ; the higher proportions are multiples of the lowest, by 2, 3, 4, and 5, at which last number, in this case, they stop. In every series of compounds we find the same law operating. If a substance can combine with more than eight parts of oxygen, the least next quantity it combines with is 16. It never combines with 8 and $\frac{2}{3}$rds, 8 and $\frac{4}{5}$ths, 8 and $\frac{9}{10}$ths, or any other fraction whatever ; but if it overstep the 8, goes right on to the 16 before it is again saturated. It may go past the 16, but in that case it cannot stop at any intermediate number, but must proceed to 24. It need not halt at 24, however, if it can go on to 32 ; or at 32, if it can combine with 40 ; and it may pass at once from 8 to 40, or to any other quantity, however large, provided it be a multiple of the original 8. The only unalterable decree is, that whatsoever smallest quantity of one body another can combine with, every higher compound must contain in increasing multiples.

In all the cases referred to, binary compounds have, for

the sake of simplicity, been taken for illustration, and they have been such, that one of the elements has remained constant in quantity, while the other has increased in the higher or more complex compounds, by multiples of the quantity found in the lowest or simplest. But cases are quite common where both of the elements of binary compounds, and all those of more complex ones, occur in multiples of their smallest combining quantities. One illustration from a small series of binary compounds may suffice. There are three well-known compounds of iron and oxygen. In the first, we have 27 parts of iron to 8 of oxygen; in the second, 54 of iron to 24 of oxygen, or the proportion of iron is doubled, and that of oxygen tripled; in the third, we have 81 iron to 32 oxygen, or the iron tripled and the oxygen quadrupled.

This law reigns through all nature, and is so manifest, that it scarcely calls for fuller illustration. Those who are quite unfamiliar with chemical speculation, however, may perhaps be able to grasp it more firmly by means of the following comparison:—A compound body is with great propriety likened to a chain, while the separate links of which the latter is made up represent its constituent ingredients. In accordance with this view, let each of the elementary bodies be represented by a link of a different length. To carry out the analogy fully, there should be a difference also in the material, colour, shape, and other attributes of the different representative links. For the sake of simplicity, however, we shall exclude the consideration of everything but the difference in length, and shall further suppose it to be such that all the links representing hydrogen are one inch long; those representing oxygen, eight inches long; those representing nitrogen, fourteen inches long, and so on with the links symbolizing the other elementary

bodies, according to the differences between the numbers expressing their combining proportions, by weight. If, then, we proceed to construct a chain by attaching these links to each other, the length of the chain will in every case be a multiple of the length of the individual links of which it is constructed. Let us, for example, connect a link of nitrogen fourteen inches long with one of oxygen eight inches long, which will give us a double link twenty-two inches in length. This is the shortest chain we can have made of these links, and will represent the lowest, or simplest compound of nitrogen and oxygen. If we proceed to lengthen it by the addition of oxygen links, we may add a single additional one, or two at once, or five, or ten, or a thousand; but whatever be the number we add, the length in inches of the part of the chain made up of oxygen links will always be a multiple of the original eight, which expressed the length of a solitary link. No fractional number will ever appear, for the chain is made up of links, none of which can be shortened, so as to be shorter than eight, or lengthened, so as to be longer.

In like manner, we might weave together, in utter darkness, and in the most random way, complicated net-works, consisting of links of different lengths, representing the fifty-six elementary bodies. But when our handiwork was brought to light, and the length of the chain-work contributed by each kind of link measured, it would invariably prove to be a multiple of the length of the primary links, by the interlacement of which the whole had been fashioned.

The law of multiple proportion belongs peculiarly to Dalton. He generalized it from a solitary case, that of the compounds of carbon and hydrogen already referred to, where the law at first sight strikes us less than it does in

many other cases, as it appears only in the duplication of the numeral 1, representing hydrogen, which is taken as unity. It was sufficient, however, to suggest it to Dalton, who unhesitatingly predicted its applicability to all kinds of compounds. He had been so far anticipated in this by one chemist, a Mr. Higgins, of Pembroke College, Oxford, afterwards Professor of Chemistry at Dublin. In a work published by that gentleman, in 1789, entitled, *A Comparative View of the Phlogistic and Antiphlogistic Theories*, he states, according to Dr. Daubeny, that one ultimate particle of sulphur and one of oxygen constitute sulphurous acid, whilst one ultimate particle of sulphur and two of oxygen constitute sulphuric acid; and, moreover, that in the compounds of nitrogen and oxygen the ingredients are to each other in the proportion of 1 to 1, 2, 3, 4, and 5, respectively. Mr. Higgins' work excited no attention at the time of its publication, nor for many years after. It was not, indeed, till Dalton's re-discovery and re-announcement of the law, that his views on the subject became generally known. It seems doubtful, indeed, if he was aware of the importance of the law he had discovered, but it should not be denied that he clearly saw and fully announced it as applying to several compounds; nor should it be forgotten, in estimating his merit, that when he published his views, there existed so very small a number of accurate analyses, that it was impossible to test its truth on any but the most limited scale. But after conceding this, we shall be guilty of no injustice to Mr. Higgins if we say, that had he seen the value and importance of the law as fully as Dalton saw it, he would have done as Dalton did, who spent ten or twelve of the best years of his life in verifying its truth by analyses of as large a series of compounds as he possibly could compass. We shall have occasion again to refer to

Higgins in connexion with Dalton ; meanwhile we proceed to the consideration of the next law.

The third law of combination is named that of *Reciprocal Proportion*, and is to the effect, that if two bodies combine in certain proportions with a third, they combine in the very same proportions with each other. Thus 16 parts of sulphur combine with 8 of oxygen, and 27 parts of iron combine with 8 of oxygen ; but 16 parts of sulphur is the very quantity that combines with 27 of iron. We may reverse the number : 8 of oxygen combines with 27 of iron, and 16 parts of sulphur with 27 of iron ; but 8 of oxygen is the very number that combines with 16 of sulphur. Or a third time : 8 oxygen and 27 iron combine respectively with 16 sulphur, but 27 iron is the quantity that combines with 8 oxygen.

This law is not only of the greatest theoretical interest, but of the utmost practical value to the chemist. But for its existence, his labours as an analyst would be endless, and the work of a lifetime would go but a short way in ascertaining the combining proportions of a single substance. As it is, however, if the proportion be ascertained in which one body combines with any one other, that, or a multiple or submultiple of that, is the proportion in which it combines with every other with which it can combine at all. A new metal, for example, *Didymium*, has been discovered by the Swedish chemist, Mosander, the combining proportion of which is still uncertain. To ascertain this, it will not be necessary to discover by actual trial what quantity of it unites with a certain weight of each of the other elementary bodies : it will suffice to know the proportion in which it unites with one of them, oxygen : this, with the qualification already stated, will be the proportion in which it combines with all the rest.

It is in relation to this law more than to the others that the combining weights of bodies are named their *equivalents* —the best title by which they can be distinguished. This term expresses, in a way no other does, that a certain weight of one body is equivalent to, or goes as far as, a certain but different weight of another in the construction of a similar compound. One part by weight of hydrogen, for example, goes as far in combining with eight of oxygen to form an oxide, as 27 of iron, 33 of zinc, 98 of platinum, or 199 of gold. These compounds have all the same value; the weight of oxygen is the same in all, and the 199 parts of gold do not neutralize the 8 of oxygen 199 times more effectually than the one of hydrogen does, but only *as* well and with the production of a *similar* compound. The same remark applies to the different but equivalent quantities of all the other substances referred to.

This law of reciprocal proportion was discovered by the German chemist, Wenzel, already mentioned, who published his views on the subject in 1777, in a work of great merit, which attracted, however, no attention at the time of its publication. In this he showed, from certain phenomena exhibited by neutral salts when they decompose each other, that the proportions in which bodies combine with each other were both constant and reciprocal. His views were taken up and followed out by his countryman, Richter, who began to publish in 1792, and confirmed the truth of Wenzel's conclusions by observations made on the precipitation of metals from solution, by each other. Richter's greatest merit, however, consisted in an endeavour to ascertain, by a series of most patient analyses of different salts, the exact weight of acid and base required for mutual saturation, and to express this by a number attached to each.

He spent some twelve years of his life in this labour, and

published various works on the subject, but his views attracted as little notice as Wenzel's, and it was not till after his death that Berzelius obtained for them the attention they deserved. All are now agreed, that though his numbers are wrong, and very far wrong too—a remark which applies equally to Dalton's first similar table—his name will ever be honourably connected with the earliest attempt to lay the foundation of quantitative chemistry.

The fourth and last law we have to consider is a very simple one, and will not require much illustration. It may be called the law of *Compound Proportion*, and teaches that the combining proportion of a compound body is the sum of the combining proportions of its components. The combining proportion of water, for example, is found by experiment to be 9 (or a multiple of 9), hydrogen, as before, being taken as unity; but nine is the sum of 8 parts of oxygen, and 1 of hydrogen, its constituents. The equivalent of carbonic acid appears upon trial to be 22; but carbonic acid is found on analysis to consist of 6 parts of carbon and 16 of oxygen, which exactly make up 22. The combining weight of lime is 28, but lime consists of 20 calcium and 8 oxygen, which are also 28. Lastly, marble has the combining proportion 50, but it is composed of 22 carbonic acid and 28 lime, which are also 50.

This law is of as much interest and practical value as the preceding one, and supplies the chemist with a most important means of checking the results of empirical analysis in the case of compound bodies. The merit of discovering it belongs entirely to Dalton. It followed so directly and unavoidably from his atomic hypothesis, that its existence was implied in the very enunciation of the latter; and we think we do not err when we say that chemists are so much accustomed to consider that law in the light of this hypo-

thesis, that the possibility of its existence apart from it is altogether forgotten.

Independent, however, it certainly is of any hypothesis, and it could not have been deduced from the other laws we have just been discussing. Although the atomic hypothesis had never been devised, it might, and certainly would, have been discovered ; and though that hypothesis should prove utterly false, it will remain equally valid, resting, as it does, on the ground of direct experimental evidence. We are the more induced to dwell on this, that even so distinguished a person as the Rev. Mr. Whewell, Master of Trinity College, Cambridge, has failed to perceive the independence and value of this law of compound proportion ; and in the discussion of Dalton's Atomic Theory in the History of the Inductive Sciences, does not so much as once mention or allude to it. The error, whether it arose from ignorance of the law, or from the supposition that it was deducible from the laws of reciprocal and multiple proportion, is almost inexplicable and quite inexcusable.

On these four laws modern chemistry is based. It has been said, indeed, of them, that chemistry before their discovery was only an art, but by their recognition became a science. But this is to say too much : chemistry as a qualitative science, *i.e.*, as a science treating of the qualities or properties of bodies, existed before their discovery, and might have existed in a state of considerable perfection as such, although they had had no place in nature, or that place had never been discovered. Their peculiar effect is to confer upon chemistry the character of a science of quantity, which till they were brought to light it did not possess ; but in so doing they widened and made more accurate its range as a science of quality. For, to take but one ex-

ample, we could not with absolute certainty affirm that water consists of hydrogen and oxygen, and of nothing else, unless we were able to show that a given quantity of water, subjected to analysis, yields weights of hydrogen and oxygen, which, taken together, are identical with that of the water analysed.

These laws, it is important to observe, contain in them nothing hypothetical. They sum up the results of the universal experience of chemists (so far as experience can be called universal), of which they are the expressions. With the exception of the law of constant proportion, they were wrought out by Dalton for himself, and by him first fully made known to the world. He did not expound them, however, in the way we have done, but employed in their enunciation the language of the ingenious and beautiful hypothesis which had led him to the discovery of two of them, and supplied a satisfactory explanation of them all. This hypothesis, generally called the Atomic Theory, we are now to consider.

Dalton began by assuming that matter, although it may in essence be infinitely divisible, is, in fact, only finitely divided, so that it consists of certain ultimate particles or molecules possessed of a definite and unchangeable weight, shape, and size. These particles he named, as others had already done, *atoms*, from the Greek, ἄτομος (*that which cannot be cut or divided*), to signify that they were indivisible. The indivisibility attributed to them, however, was not affirmed to be absolute, so that they could not by possibility be reduced in dimensions, and broken up into smaller particles, but was held to exist in relation only to the chemical and other disintegrating forces existing in nature, none of which were supposed able to divide them. According to this view, then, ponderable masses or volumes of the different ele-

mentary bodies were supposed to consist of a countless multitude of undivided atoms.

On the shape of these atoms, Dalton offered no opinion, though he thought it probable that they were spherical, and drew them as such in his diagrams. Neither did their size enter as an element into his speculations, and it need not into ours; all, indeed, that we know on the subject or can affirm is, that they are inconceivably small; so small, indeed, that to say how many could stand at the same time on the point of the finest needle would be a problem as difficult for the modern physicist, as it was hard for the schoolmen of the middle ages to decide how many angels could be accommodated at once on the same airy pinnacle.

Up to this point there was nothing novel in Dalton's views. For centuries an atomic constitution of matter had been held as probable by many, and defended by all the arguments that physics and metaphysics could supply. For the sake of contrasting these earlier views, which were almost purely physical, or referred to the atoms of homogeneous combinations of matter, with those of Dalton, which were chemical, or had reference to the atoms of heterogeneous compounds, we shall quote the exposition of one of the ablest of Dalton's predecessors:—

'All things considered,' says Newton, 'it seems probable that God, in the beginning, formed matter in solid, massy, hard, impenetrable, movable particles, of such sizes, figures, and with such other properties, and in such proportion to space, as most conduced to the end for which he formed them; and that these primitive particles, being solids, are incomparably harder than any porous bodies compounded of them; even so very hard as never to wear or break to pieces, no ordinary power being able to divide what God made one in the first creation.'

Newton, it will be observed, says nothing concerning the weight, either absolute or relative, of his primitive particles. The former was manifestly beyond the reach of human discovery, and nothing was known in his day which could throw any light on the latter.

It is here that Dalton, introducing the question of weight, leaves Newton behind, and takes not a step, but a stride, in advance of all previous speculators on atomics. His early physical inquiries, as we shall afterwards find, had accustomed him to form the clearest and most precise conceptions of matter as made up of atoms, and as soon as he obtained the faintest glimpse of the laws of combining proportion, he connected it with these familiar speculations, so that his atomic hypothesis rose into full perfection before he had completed the analysis of so many as a dozen compounds.

This immediate perfection was given to his hypothesis by the one bold conjecture, that the ultimate atoms of the elementary bodies do not possess the same, but different weights; and that the difference between their weights is identical with that which subsists between the combining proportions of the elements themselves. As oxygen, for example, has a combining proportion eight times greater than that of hydrogen, so the ultimate atom of oxygen is assumed to be eight times heavier than the ultimate atom of hydrogen. As the combining proportion of nitrogen is fourteen times that of hydrogen, so the atom of nitrogen is supposed to be fourteen times heavier than that of hydrogen; and in like manner the relative weights of the atoms of the other elementary bodies are supposed to differ by the same numbers that the relative weights of their combining proportions differ by. Dalton, it will be observed, no more than Newton, pronounces on the absolute

weight of his atoms; all, in truth, that he could have said on that point would have been, that they were so inconceivably light, that it would require millions of the heaviest of them to turn the most delicate balance. But he thought, that if it were possible by any means to select single atoms of each of the elementary bodies, and weigh them, one by one, we should find, *first*, that different atoms of the same element possessed all the same weight, so that whatever was the absolute weight of any one would be found to be the weight of each of the others of the same kind; and if one atom of hydrogen weighed the millionth of a millionth of a grain, each of the hydrogen atoms would weigh the millionth of a millionth also; *secondly*, we should find that all the oxygen atoms were 8 times heavier than the hydrogen ones; all the nitrogen, 14 times heavier; all the silver atoms, 108 times; all the gold atoms, 199 times heavier. In short, the proportions in which bodies combine with each other are supposed to depend upon the weights of the atoms which make them up, and to be identical with them. All the numbers, accordingly, which before this hypothesis is considered, represent combining proportions, as soon as it is adopted, come to represent weights of ultimate atoms, or atomic weights.

According to this view, then, when bodies combine together, their ultimate particles do not interpenetrate, or become fused together so that the individuality or identity of any is lost. The atoms only come into close proximity, and lie side by side, or above and below each other; and when the compound they form is decomposed, they separate, and reappear with all their original properties. The smallest possible quantity of water is in this way conceived to consist of one atom of hydrogen and one of oxygen, bound together, without loss of the individuality of either,

by the unknown and invisible tie which we term chemical affinity.

Such is the atomic hypothesis : how beautifully it explains all the laws of combining proportion will appear on a moment's reflection. A law of *constant* proportion, such as we have learned, must obtain in the combinations of atoms, possessed of the properties Dalton assumed, for their relative weights are unalterable, and there is therefore but one lowest, or smallest, proportion in which they can combine. The weight of an atom of oxygen is 8, and that of an atom of hydrogen, 1. It is impossible, therefore, that their smallest combining proportions, by weight, should be any others than 8 and 1.

A law of *multiple* proportion is equally necessary, for an atom of one element is the smallest quantity that can be added to a compound containing an atom of it already, and whatever was the weight of the first atom will be that of the second also, so that an exact duplication of the first proportion, without any fractional lack or excess, must take place. And if more than one atom be added at a time, it must be atoms, not an atom and a half, or one and a third, or any other fraction or fragment, for this cannot be, seeing that the atom is indivisible.

In the five compounds of nitrogen and oxygen already considered, the first, which contained 14 of the former to 8 of the latter, was to be taken as a compound of a single atom of each. The second must contain 16 oxygen, because the next highest compound must be one of two atoms ; the third, 24, because there are three atoms, each weighing 8 ; the fourth, 32, because the atom is quadrupled ; and the fifth, of necessity, 40, for a similar reason.

It is almost unnecessary to continue the application of Dalton's hypothesis to the other two laws, it is so direct

and unavoidable. The law of reciprocal proportion is an inevitable result of the constancy in weight of the atom. For if an atom of iron is found to be twenty-seven times heavier than one of hydrogen when weighed along with one of oxygen, and if an atom of sulphur be sixteen times heavier than one of hydrogen when also weighed with one of oxygen, then the atom of iron will continue to weigh 27, and that of sulphur 16, when they are weighed together ; for these were the weights of the iron and the sulphur atoms before they combined ; they remain so during their combination ; and will reappear so whensoever they separate. In a word, the weight of an atom is a constant quantity ; it cannot be lessened, or increased, or annihilated. Finally, the law of compound proportion is so necessary, that it was anticipated through this hypothesis before it was found in nature. There could not fail to be such a law, in virtue of the constancy in weight, and the indivisibility of the atom. For the aggregation of atoms does not alter their weight, and the atom cannot divide, so that its weight should be shared among smaller molecules. Had the atom been divisible, it might have been otherwise, and when two or more atoms entered into combination, they might have broken up into lesser particles, among which the original weight was parcelled out. In this way, the compound made up of them might have had the same, or a smaller combining weight than that possessed singly or together by its components. According to the atomic hypothesis, the combining proportion, or atomic weight of water, is *necessarily* 9, because it consists of two atoms weighing respectively 8 and 1. But if these had not been indivisible, they might have broken up in the act of combining, and yielded not one particle weighing 9, but, for example, nine particles, each weighing 1, so that the

combining weight of each particle of water should have been no greater than that of the original particles of hydrogen.

Such, then, was the chemical doctrine of atoms, in its first announcement, as related to the laws of proportional combination by weight. Before we consider the steps by which Dalton was led to its announcement, or proceed curiously to dissect and criticise it, let us stop for a moment to give it the deserved tribute of our admiration. It claims this at our hands, on the twofold ground of its beauty as a method of expressing the order and symmetry of material nature, and its value as a means of apprehending and inculcating great chemical truths. We may afterwards find it unnecessary to concede to Dalton's atoms the attribute of indivisibility, even in the limited extent to which he conferred that property upon them, and see reason to believe that a potential, or virtual, not an actual atom is all that chemistry requires for the solution of her problems: nay, that the potential is better than the actual atom for the explication of many of them. But placing the question of its truth aside for the present, we cannot forbear to mark the grand idea which the Daltonian atomic hypothesis gives us of the law and order which prevail in nature.

In the light of it, there is nowhere any 'fortuitous concourse of atoms,' as the Roman poet proclaimed of old; no crash or collision, no strife or warfare, when they meet together, as Milton sang, in relation to the embryon atoms of his chaos. According to this view, the courses of the planets around the sun are not more surely ordered than the movements of these invisible spheres round the centres of force which they obey. Arcturus and Orion know not their places better than each tiny gold or hydrogen atom

which adds its weight to swell the sum-total of the universe. And if poets of old have sung of the music of the spheres which the telescope unfolds to us, poets, we doubt not, will yet be found to sing of the harmony, as true and as wonderful, which attends the movements of those which the finest microscope will never reveal. Nay, we know not that we have to wait for a poet to do so, for one who will never be excelled has declared to us that—

> 'There's not the smallest orb . . .
> But in his motion like an angel sings.'

We might recur to our simile of the chain-work, and speak of atomic nature as a glorious garment woven out of links of different kinds, which Infinite Wisdom, at the first creation, forged of the shape, and length, and size which it best fitted each of them to possess.

Or we might liken these atoms to coins stamped in Nature's mint, of definite and unchangeable value, with which she pays all the demands the animate and inanimate world make upon her; but this illustration falls much below the dignity of the theme.

Rather would we have recourse to that old and familiar, but lofty and suitable one, which speaks of this world as a temple;—a temple built by God to his own glory, and for the good of his creatures. And if we did so, we should speak of it, not as of a Cyclopean wall piled out of unwieldly and misshapen blocks, flung as if by Titanic hands together; nor as of a Tower of Babel, where, amidst confusion of tongues, one asked for bricks and another gave him mortar; but as of a structure such as the Hebrew king built to his God, where 'the house, when it was in building, was built of stone made ready *before it was brought thither*,' and the 'great stones, costly stones, and hewed stones' were each carved and chiselled to fit its appointed

place before the builder began, 'so that there was neither hammer, nor axe, nor any tool of iron heard in the house while it was in building;' but,

> 'Out of the earth, a fabric huge
> Rose like an exhalation, with the sound
> Of dulcet symphonies and voices sweet
> Built like a temple.'

On the atomic hypothesis, considered merely as a figment or artifice for expressing simply the laws of combining proportion, it is unnecessary to say much, its value in this respect is so apparent. To the student who, with difficulty, has been struggling to form a clear conception of equivalents, proportions, and the like, which, after all, he apprehends only as shadowy, ponderable masses of equal value, the passage is like that from morning twilight to full day, when he grasps firmly the idea of different atoms like separate spheres, each a perfect whole, possessing a definite and unalterable weight. The movements and relations of the equivalent atoms can thereafter be as readily followed in thought by the chemist in his speculations, as those of suns, or of planets and their satellites, by the astronomer, in the calculations which the science of the heavenly bodies demands. Nor is any revelation which chemistry seems destined to undergo, even should it bring about the decomposition of all the so-called elementary bodies, likely to lessen, or even much to alter, the value of the atomic hypothesis, considered as a device for inculcating chemical truths. On this subject, therefore, we say no more, but at once pass to a question of the highest interest.

The first glimpse of his 'Atomic Theory' was obtained by Dalton in the course of certain researches into the solubility of the different gases in water, which he published in

the Manchester Society's Transactions for the year 1803. In 1804, he 'touched upon it in his lectures' in Manchester, and at the Royal Institution in London, and in the same year he explained it in conversation to Dr. Thomson, of Glasgow, who spent a day or two with him at Manchester.

By the latter chemist, and not by Dalton himself, it was first explicitly made known to the world, in the third edition of his *System of Chemistry*, published in 1807, four years after its first partial announcement to the Manchester Society. In the same year, Dalton expounded his views in a course of lectures delivered in Edinburgh and in Glasgow, the greater part of which, however, was devoted to the exposition of his discoveries in relation to heat; and in 1808, the substance of these lectures was published in his well-known work, entitled, *New System of Chemical Philosophy*. We cannot, therefore, consider the atomic theory as having come fully before the world till the latter year.

Up to the present time, so far as we are aware, no attempt has been made to trace the steps by which Dalton was led to his greatest discovery, although the evolution of these in a systematic way would have strengthened almost incalculably the argument of those who sought to defend his merits against the claims of British and foreign rivals; and the history of their development would have been welcomed by all who took an interest in scientific inquiry.

We shall endeavour, so far as our limits permit, to supply this deficiency; premising, however, that we have not had access to any private sources of information, but derive our knowledge solely from works which are, or may be, in the hands of all. In nearly every one of the memoirs which have been published concerning Dalton and his discoveries, we are simply told, in the words of Dr. Thomson, that the 'atomic theory' first occurred to the former

during his investigation of olefiant gas and carburetted hydrogen, which were imperfectly known when he undertook their investigation. A conclusion naturally drawn from this statement is, that the laws of combining proportion were discovered in the course of an analytical inquiry, undertaken expressly for the purpose of ascertaining what they were, and that the atomic hypothesis was devised after the laws were discovered as a means of explaining and expounding them. It was not so, however. On the other hand, we shall presently see that it was in the course of a purely physical inquiry into certain of the properties of a single class of bodies, the gases, that Dalton was arrested by a difficulty which obliged him to analyse several of those which are compound, such as the carburetted hydrogens. The result of these inquiries so completely fell in with his previous speculations, that he flung forth his atomic hypothesis as soon as he met with a single case of combination in multiple proportion.

The path along which Dalton travelled was somewhat like the following:—The blind gentleman, Mr. Gough, who exercised so beneficial an influence over his early days, added to his other tastes a love for meteorology. 'It was he,' Dalton tells us, 'who first set the example of keeping a meteorological journal at Kendal;' and his pupil appears to have soon acquired a relish for the same study. Doubtless he was influenced likewise by the magnificent scenery around him, of which he has left some eloquent descriptions, and was tempted by the peculiar facilities which the locality of his residence afforded for every kind of meteorological inquiry. At all events, he commenced in 1788 those daily observations which were continued for fifty-five years, and led to the publication, in 1793, of the 'Meteorological Essays,' already referred to. It was impossible for Dalton,

however, to content himself merely with recording the risings and fallings of the thermometer and barometer, or with counting the number of inches of water in his rain-gauge. Yet to take up meteorology as a science, was to enter on a study which required for its successful prosecution a knowledge of almost every one of the other physical sciences; and even their concentrated light, when directed upon it, did not suffice for the solution of more than a small number of the problems which perplexed the student at the time that Dalton entered on his inquiries. The theory of the winds was exceedingly obscure: the connexion between alterations in the temperature of the atmosphere and the fall of rain or dew, or the opposite phenomenon of the spontaneous evaporation of water from the surface of the earth, was completely misunderstood: the nature of the force which elevated the vapour of water into the air, and maintained it and the other gases of the atmosphere in a state of equable diffusion through each other, in spite of great differences in relative density, had not been recognised; and the chemical composition of the air, and many other points of the highest importance, were either greatly misapprehended or utterly unknown. Much assistance towards the elucidation of these difficulties might doubtless have been derived from works published before Dalton commenced his researches. But a single private library could supply but a very small number of these, and no public collection of books appears to have been within his reach while at Kendal. He was, moreover, eminently a self-reliant man, and debarred from books, of which, it must be acknowledged, even when he could get them, he was no great reader; he set to work to solve, by actual experiment, the problems which his meteorological studies had brought into view. Little could be done

towards this whilst he resided among the lakes, but as soon as he reached Manchester, he gave himself assiduously to such employment, and the two great objects of his researches were the laws which regulated the action of heat in changing the forms of bodies, the discovery of which was certain to throw light upon the questions of dew, rain, hail, evaporation, etc., and the physical constitution of vapours and gases, which bore upon almost every question in meteorology. A very brief review of Dalton's earlier contributions to the Manchester Society's Memoirs will show the exact nature of these inquiries, and serve the important incidental purpose of giving the reader some acquaintance with his purely physical researches. Our space will not allow us otherwise to refer to these, but in commenting thus scantily upon them, we would not omit noticing that, as it has often happened in other cases, the greatness of one of Dalton's discoveries has thrown into shade all his others. It is certain that, although he had never unfolded his views on chemical atomics, he would have taken a very high place among men of science; and we encourage the belief that the method we are adopting in expounding his views, will have the effect of linking together in their natural connexion his physical and chemical speculations.

The first paper, read October 31st, 1794, is entitled, 'Extraordinary Facts relating to the Vision of Colours,' and referred to a remarkable peculiarity in his perception of the tints of bodies which will be considered in another place. The second, read March 1st, 1790, contains 'Experiments and Observations to determine whether the quantity of Rain and Dew is equal to the quantity of Water carried off by the Rivers, and raised by Evaporation; with an inquiry into the origin of Springs;' and may be considered a demon-

stration, in the eighteenth century, of the truth of what the wise king had declared some thousand years before—'All the rivers run into the sea, yet is the sea not full; unto the place from whence the rivers come, thither they return again.' The third communication, read April 12th, 1788, entitled, 'Experiments and Observations on the power of Fluids to conduct heat,' was an ample and satisfactory refutation of Count Rumford's supposition, that fluids were non-conductors of caloric. It does not, however, particularly concern us. In the fourth paper (June 27th, 1800), 'Experiments and Observations on the Heat and Cold produced by the mechanical condensation and rarefaction of Air,' he returns to inquiries connected with meteorology. The next contributions, read October 2d, 16th, and 30th, 1801, but published in one memoir, are his celebrated 'Experimental Essays on the Constitution of mixed Gases; On the force of Steam or Vapour from Water and other liquids in different temperatures, both in a Torricellian vacuum and in air; On Evaporation; On the Expansion of Gases by Heat.' The only section of this elaborate memoir to which we can refer is the first. It affirms the startling and apparently incredible proposition, that 'when two elastic fluids, denoted by A and B, are mixed together, there is no mutual repulsion amongst their particles—that is, the particles of A do not repel those of B, as they do one another; consequently, the pressure or whole weight upon any one particle arises solely from those of its own kind.' Guided by this remarkable idea, Dalton proceeds to the consideration of mixed gases, and particularly of the atmosphere, and applies his views with great success to the removal of the difficulty attending the consideration of the cause of the constant composition of the air we breathe. To all previous speculators, who denied that the air was a chemical

compound, as Dalton did, there remained unanswered the question—How do the constituents of the atmosphere exist in a state of equable diffusion through each other, in spite of the difference in their relative densities? Should not the heavier, oxygen, be found near the surface of the earth; the lighter, nitrogen, in the higher regions? No difference exists in this respect, and Dalton's hypothesis takes away all necessity for there being any. We have referred to this subject with a view to direct the reader's attention to a plate which is placed at the end of the paper, illustrating the constitution of our atmosphere as consisting, according to this hypothesis, of gases self-repulsive, but indifferent to each other. The particles of oxygen are represented by small rhombs or diamonds; those of nitrogen, by dots; those of carbonic acid, by triangles; and those of aqueous vapour, by asterisks. The reader will see the importance of this reference, as showing that, two years before he published his 'Atomic Theory,' Dalton had accustomed himself to the most precise views as to the properties of masses or volumes of bodies, resulting entirely from those of their ultimate particles, and pictured these to himself and to others by various significant symbols. There was not, probably, among the men of science of his time one who apprehended more clearly than he did that the properties of any mass, however great, are in every case the sum or the difference, or otherwise the expression, of the properties of the ultimate molecules, particles, or, as he afterwards came to call them, atoms, of which it consists. It is to be observed, however, that the word *atom* nowhere occurs, but is represented in every case by the equivalent term, 'ultimate particle.'

We pass over the next paper, which records 'Meteorological Observations made at Manchester, from 1793 to

1801,' and take up the succeeding ones, which are closely connected with the essay we have just been discussing.

The first was read November 12th, 1801, and is entitled, 'Experimental Inquiry into the proportion of the several Gases or elastic Fluids constituting the Atmosphere.' Its title sufficiently explains its object. It was followed, on January 28th, 1803, by an essay 'On the tendency of elastic Fluids to diffusion through each other;' a remarkable paper, carrying out the observations of the older pneumatic chemists, and especially Priestley, that elastic fluids of different specific gravities, if once diffused through each other, do not separate by long standing, so that the heaviest is found lowest, but remain in a state of uniform and equal diffusion. Dalton showed further that gases intermix with each other independently of agitation, although the one be much heavier than the other; so that carbonic acid, which is twenty-two times heavier than hydrogen, will rise into the latter, and the hydrogen conversely descend into it. The subject was afterwards more fully examined by Professor Graham, of London, in a memoir of the highest interest.

We have nearly completed our abstract. The next paper, read October 21, 1803, the last, probably, in which, from its title, 'On the Absorption of Gases by Water and other Liquids,' the reader would look for it, contains the first announcement of Dalton's discovery of the laws of combining proportion, and the germ of the 'atomic theory.' After stating the laws which he had found to regulate the absorption of gases by water, he proposes a theory in explanation of it, according to which he contends that gases, such as oxygen, nitrogen, carbonic acid, etc., when in aqueous solution, are mechanically mixed with water, not chemically combined with it—a view which has not been

adopted by other chemists. 'Gases so mixed with water,' says he, 'retain their elasticity or repulsive power among their own particles, just the same in the water as out of it, the intervening water having no other influence, in this respect, than a mere vacuum.' He goes on to compare his gas dissolved in water to a pile of shot—'a particle of gas pressing on the surface of water, is analogous to a single shot pressing upon the summit of a square pile of them;' and on the opposite page he has inserted an engraving of a pyramidal pile of balls left unshaded, with a dark ball surmounting the apex. This is entitled, 'View of a square pile of shot, etc. The lower globes are to represent particles of water; the top globe represents a particle of air resting on particles of water.' Further on are two other engravings, the one of a 'Horizontal view of air in water,' the other a 'Profile view of air in water,' in which dots and crosses are taken to represent particles of air, with spaces of water between them. We have specially referred to these engravings, as affording additional illustrations of the hold which a belief in the atomic constitution of matter had taken of Dalton's mind, and the use which he made of it in discussing purely physical problems (or, at least, what he considered such), before he had occasion to apply it to chemical questions at all. At the close of the essay comes the acknowledgment of the difficulty which attends a hypothesis of mechanical absorption. If the mingling of gases with liquids, on which they do not act chemically, be but a mechanical action, like the mingling of indifferent gases with each other, how happens it that water dissolves its own bulk of one gas, such as carbonic acid, and only three per cent. of its volume of another, such as oxygen? We should expect, if the mechanical view were true, that all gases should be equally soluble in water; for if water act

as a vacuum would do, it must act in the same way on every gas. Dalton saw the difficulty, and devised a hypothesis to overcome it. We give his own words :—'Why does water not admit its bulk of every gas alike ? This question I have duly considered, and though I am not yet able to satisfy myself completely, I am nearly persuaded that the circumstance depends upon the weight and number of the ultimate particles of the several gases : those whose particles are lightest and single being least absorbable, and the others more, according as they increase in weight and complexity.' To this there is a foot-note—'Subsequent experience renders this conjecture less probable.' And the text is followed by a passage which we print in italics—'*An inquiry into the relative weights of the ultimate particles of bodies is a subject, as far as I know, entirely new ; I have been prosecuting this inquiry with remarkable success.*' On the succeeding page is a 'Table of the relative weights of the ultimate particles of gaseous and other bodies.' This was the first table of *atomic weights*, and every one of them was wrong, with the exception of hydrogen, which was assumed as unity. We extract four of the numbers :

Hydrogen	1
Oxygen	5.5
Carburetted hydrogen from stagnant water .	6.3
Olefiant gas	5.3

Such, then, were the steps by which Dalton was conducted to the discovery of the laws of combining proportions. He was testing, by experiment, the truth of a hypothesis as to the cause of the specific solubility of gases in water, which proved in the end to be quite untenable ; but, like Columbus, who missed an El Dorado, but found an America, he discovered something better. From what Dr. Thomson tells us, he was struck by observing that the quan-

tity of hydrogen in fire-damp is exactly twice that in heavy carburetted hydrogen, the quantity of carbon being the same in both. His constant reference of the properties of masses to those of their smallest molecules led him at once to connect these proportions, in which the carbon and hydrogen occurred, with the relative weights of their ultimate particles. We may suppose him to have reasoned somewhat thus—'Hydrogen and carbon are made up of particles which have different weights, the carbon atoms being all six times heavier than the hydrogen ones, but if hydrogen and carbon have atoms differing in relative weights, oxygen, nitrogen, and every other elementary substance will have atoms differing in relative weight also; and these may be ascertained by finding the relative weights according to which the masses made up of them combine with each other.' To Dalton's mind, filled, as it were, already with the conception of everything consisting of atoms, it was only necessary to introduce the additional idea of these atoms differing in relative weight, and all the laws of combining proportion rose at once into view. He was gifted with a bold, self-reliant, far-glancing, generalizing spirit, and the researches he had long been prosecuting had doubtless strengthened greatly that faith in the uniformity of nature's laws which we all inherit as an essential part of our mental constitution. We may believe that, without an effort, and almost instinctively, he would infer that if hydrogen followed a law of multiple proportion in its higher combinations with carbon, a similar relation would be found to hold in every case where the same elements united to form more than one compound. The detection of the other laws of combining proportion must have been immediate; but this has been so fully illustrated already, that we need not enter on the subject again. It must never be

forgotten that Dalton's atomic views gave him the same advantage in detecting the laws of chemical combination which they afford us in apprehending and expounding them.

In confirmation of the view we have taken of the development of the atomic hypothesis, we would refer to Dalton's contributions to the first six volumes of the 'Manchester Memoirs,' which, gone through consecutively, will conduct every reader, we believe, to the conclusion we have arrived at. It is confirmed by Dalton's reference to the carburetted hydrogens already considered, and by the way in which Dr. Thomson introduces the earliest published account of the atomic theory, not while discussing chemical affinity or the laws of combination, but quite abruptly under the head of the density of the gases. Dalton himself always connected his later chemical with his earlier physical discoveries. When he published the second edition of his 'Meteorological Essays,' in 1834, forty-one years after the publication of the first, he said, in reference to the few alterations it contained—'I have been the more anxious to preserve the first edition unchanged, as I apprehend it contains the germs of most of the ideas which I have since expanded more at large in different essays, and which have been considered discoveries of some importance.'

We wind up this long discussion with a single remark. Dalton's views of chemical combination, including both the facts and the hypothesis which expressed and explained them, are generally known as his 'Atomic Theory.' To Dalton himself the evidence in support of the existence of ultimate indivisible particles appears to have seemed so conclusive, that he considered the doctrine of atoms in the light of an induction from the data furnished by observation and experiment; and this without reference to any other than purely physical questions. We cannot, indeed, suffi-

ciently reiterate that he was an atomist before he was a chemist. In his lips, therefore, the name 'Atomic Theory' was consistent, and had a clear meaning. It was John Dalton's atomic theory of chemical combining proportions; his theory of atoms connected with his discoveries in chemistry, so as at once to account for, and to expound them. To those, however, who cannot by any process of generalization establish to their own satisfaction, or to that of others, the actual existence of atoms (and it includes almost every one who thinks on the subject at all), and for whom the doctrine of atoms is only a questionable, and, we may say, an indifferent hypothesis, Dalton's view is 'an atomic hypothesis of combining proportion.' It matters comparatively little, however, whether we say atomic theory or atomic hypothesis, provided we keep perfectly distinct what is matter of assumption concerning atoms, from what is matter of fact concerning laws of combining proportion.

The only chemist who has adopted Dalton's views is Dr. Thomson, who affirms that 'unless we adopt the hypothesis with which Dalton set out—namely, that the ultimate particles of bodies are *atoms* incapable of further division, and that chemical combination consists in the union of these atoms with each other—we lose all the new light which the atomic theory throws upon chemistry.' Dalton's other contemporaries—Davy, Wollaston, and Berzelius—on the other hand, protested against confounding the question of atoms with that of combining proportions, and declined to employ the word *atom*. Davy substituted the term *proportion*; Wollaston, that of *equivalent*—the best of all the titles by which the combining weight of a body can be indicated. Notwithstanding this, it is notorious that the word *atom* is universally employed; the phrase *equiva-*

lent comparatively seldom. Some of Dalton's less discriminating admirers have built much upon this, as showing that even the opponents of an atomic view of matter are obliged to use its phraseology. This is true so far as the *word* atom is concerned; but in the language of a chemist of the present day, that term has no other meaning than the phrase *equivalent;* to which it is preferred only, we believe, because it contains half as many syllables, and is more easily pronounced. Liebig has justly observed that the use of the word *atom* is like that of the term *element.* The latter does not signify a body that *cannot be*, but only one that *has not been* decomposed; *atom*, not a particle which cannot be, but only one which, up to a certain point, has not *been* divided. Hence the chemist has no scruple in applying the term *atom* to a group of molecules considered as a whole, although he is quite certain that this compound whole may be, and often is, divided. He speaks, for example, of an atom of water, of carbonic acid, of sugar, and the like.

The announcement of the atomic theory to the chemists of Europe was like a lighted torch passed round among lamps, trimmed and filled with oil, and ready to be kindled. Some heard with incredulity, like Davy; others with gladness, like Thomson; none, probably, without astonishment, that the humble teacher of mathematics had extracted more meaning out of his imperfect and even inaccurate analyses than they, even Berzelius and Wollaston, out of their scrupulously exact ones. It was so, however. In Spain, France, Germany, Sweden, and elsewhere, many were seeking to discover the laws regulating chemical combination, every one of them probably acquainted with a wider range of chemical phenomena, and a better analyst than Dalton; but he beat them all. So true is it what

Thomas Carlyle says, that 'the eye sees what it brings the power to see.' No great discovery, perhaps, was ever welcomed so heartily and immediately as the announcement in the atomic theory of the laws of combining proportion. The chemists looked over the analyses recorded for other purposes in their laboratory books, and found on every page ample confirmation of Dalton's discoveries. Davy, Thomson, Wollaston, but above all, Berzelius, furnished every day better proofs than Dalton himself could show, that in every essential point his views were as just as they were beautiful and original. The question of Dalton's exact merit was at one time a good deal discussed, and is certain to be made matter of discussion again, as soon as a complete memoir of him is published. The sketch we have given of the path by which the atomic theory was reached enables us, we think, to set at rest the question of the rival claims of Higgins and others.

In deciding the question of merit in reference to any scientific discovery, three points require in every case to be considered. The first, the question of time — Who earliest made the discovery? The second, the question of desert—Who had the greatest merit in making it? The third, the question of practical effect—Who aroused the world by his discovery, and made it tell upon the progress of science? The last is, if not the only, at least the main point in the popular estimation of the merits of discoverers. It is our office to see that the two former receive at the hands of all equal consideration.

The question of time admits of no dispute. The law of constant proportion had been recognised by Bergmann and Proust, not to mention others, before Dalton's time, nor did he ever claim its discovery. The law of reciprocal proportion was made out completely by Wenzel and Richter,

in 1777. The law of multiple proportion was recognised clearly and fully by Higgins, in 1789. The law of compound proportion was discovered by Dalton, in 1803. This is the state of matters so far as time is concerned, and leaves no choice in the adjudication of merit in regard to the question of priority of discovery. Justice admits of no degrees. We should be as honest in handling our neighbour's character, as in handling our neighbour's money: as careful to protect the reputation of the forgotten Higgins, as to exalt the memory of the immortal Dalton.

So far as intrinsic merit is concerned, we take it for granted that no one will call in question Dalton's honesty, or doubt that, when he said, 'An inquiry into the relative weights of the ultimate particles of bodies is a subject, as far as I know, entirely new,' he faithfully expressed his entire ignorance of what Wenzel, Richter, and Higgins had done before him. It is certain that, in 1803, the views of these writers were quite unknown in Great Britain, even to those most conversant with the scientific literature of the day, and that Dalton did not become acquainted with the views of Higgins, at least, until the year 1810. If this be acknowledged, it follows that Dalton's merit as a discoverer is at least equal to that of his three predecessors taken together, for he found out for himself the laws which they only made out among them, and brought to light another, of which they were ignorant altogether.

The question of practical effect has been considered already. We have seen that it was Dalton who changed the state of chemistry. Dalton! who, while his contemporaries were with difficulty building up a fragment of scaffolding here and there at separate corners, with the far-distant hope of ultimately raising by their combined

efforts the structure of chemistry another storey, was in silence preparing to supplant them all; Dalton, who, with the aid of a cunning engine of his own devising, uplifted at once the four corners, and planted the stately edifice on a new and stable basement, from which it towered above the bogs and quicksands which had been like utterly to overwhelm it before.

Four reasons may be given why Dalton's views on combining proportion should have attracted more attention than those of his predecessors. *First*, Chemistry was riper and readier for the discussion of laws of combination than in the days of Wenzel or Richter, or when Higgins first wrote.

Secondly, Dalton's atomic hypothesis made the apprehension of the laws taught by means of it infinitely more easy than it had been before.

Thirdly, All the laws of combining proportion were taught together, and made to tell with their united force upon the mind.

Fourthly, Dalton's high character as a discoverer, and his wide reputation among men of science before he announced his atomic theory, secured for it an immediate attention which was not shown to the works of his less distinguished predecessors.

In ending the discussion of the question of merit, we would express our hope that no inconsiderate admirer of Dalton will rob his predecessors of their scanty, but hard-earned laurels, to add an insignificant leaf or two to his full-crowned head. He would have been the first himself to reject any such borrowed honours.

Here we resume the long-dropped thread of biographical detail. Our space will not allow us to prosecute it to any considerable extent. We have deemed it better, however, to discuss at some length those great questions connected

with Dalton's discoveries and scientific reputation, which have never been brought before the public, than to occupy the reader with matters, however interesting, connected merely with his personal history, many of which have been published already in various ways.

Between the years 1803 and 1810, Dalton was occupied in the prosecution of analyses to verify his atomic theory ; in teaching mathematics ; and in delivering lectures in Manchester, London, Edinburgh, Birmingham, Leeds, and Glasgow. He was not a fluent speaker, nor had he any great talent for teaching. He declined, however, all the offers made by his friends to provide him with a competency so that he might devote his undivided attention to scientific pursuits. To such overtures he replied, 'that teaching was a kind of recreation, and that if richer, he would not probably spend more time in investigation than he was accustomed to do.'

For many years he had the usual fate of the prophet, and 'received no honour in his own country.' He had always around him in Manchester, however, a small circle of appreciating friends, who did all they could to extend his fame. In 1814, they had his protrait painted by Allen, and an engraving was made from it, which has long been out of print. In 1817, they conferred on him a further mark of their esteem by electing him President of the Literary and Philosophical Society, of which he had long been the most distinguished member. He was re-elected every year till his death.

When Sir John Ross sailed on his first Polar voyage, Government and Sir Humphry Davy together thought it a fitting opportunity for doing Dalton a service, and offered him the post of natural philosopher to the expedition. But he declined the appointment, probably thinking that the

North Pole would not present many advantages for confirming by experiment his atomic theory ; and that if they had been very anxious to serve him, they might have found better means, and nearer home, for so doing. He continued, accordingly, at Manchester, teaching, experimenting, and writing scientific memoirs ; and we find nothing remarkable to record till the year 1822, when he visited France. He carried with him to Paris a single letter of introduction to M. Breguet, a celebrated chronometer-maker, and member of the French Institute. He could not have been introduced in a better quarter. Breguet was well known to the Parisian *savans* as the inventor of a metallic thermometer which bears his name ; and being wealthy and fond of the society of men of science, was in the habit of assembling them round his table. He was well acquainted, moreover, with Dalton's researches, especially those upon heat, and at a former period had sent him a present of one of his thermometers. Through Breguet, Dalton was immediately introduced to La Place, and by him to all the more distinguished French philosophers. He was subsequently invited to the meetings of the Institute, where he was most heartily welcomed, and during the whole period of his residence in Paris was treated, both in public and in private, as one whom all delighted to honour.

The generous appreciation of his merits shown by the French, as contrasted with the indifference to these exhibited by all but his personal friends and a few men of science among his countrymen, made a strong impression upon Dalton. Although a man of few words, little given to betray his feelings, and very indifferent to applause, he was so moved by his reception as to say, when he returned home—' If any Englishman has reason to be proud of his reception in France, I am that one.'

At length his countrymen became more alive to his merits; and if we have to acknowledge that the Celtic fire of our Gallic neighbours blazed forth into admiration at a time when our colder Saxon natures had scarcely begun to glow, it must be admitted, on the other hand, that when the latter began to warm, they rose steadily to a red, even to a white heat of unbounded admiration. For the last ten years of his life, Dalton was the object of universal esteem among his countrymen.

In 1826, the Council of the Royal Society of London unanimously awarded to him the royal gold medal of fifty guineas value, placed at their disposal by George IV. But it is to the British Association for the Advancement of Science that Dalton was indebted for the estimation in which latterly he was held.

He attended its earliest meeting at York, in 1831, where he was seen for the first time by many who had long esteemed him at a distance, and now rejoiced in an opportunity of vying with each other in showing him respect.

At the next meeting of the Association, held at Oxford, in the following year, the University conferred upon him the title of Doctor of Civil Law. In 1833, when the Association met at Cambridge, the President, Professor Sedgwick, took a public opportunity of expressing his regret that the University could not honour herself, as the sister one had done, by conferring upon Dalton an honorary degree, as these cannot be granted without royal mandamus. At the close of his speech, he announced 'that His Majesty King William IV., wishing to manifest his attachment to science, and his regard for a character like that of Dr. Dalton, had graciously conferred on him, out of the funds of the Civil List, a substantial mark of his royal favour.' This 'substantial mark' was a pension of £150, which was raised

to £300 in 1836. It is not generally known, but we have the best authority for stating it, that the Rev. Dr. Chalmers was the first to rouse the Government to a sense of Dalton's claims. To his purely professional and literary accomplishments, the celebrated Scotch divine added no inconsiderable acquaintance with most of the physical sciences, and the widest sympathy with the progress of them all. In early life, he is known to have been an indefatigable experimenter, and has even lectured to select audiences on heat and on chemistry. Knowing well what Dalton's merits were, he visited him at Manchester, and was surprised and pained to find him an obscure, ill-remunerated teacher of Mathematics. Dr. Chalmers lost no time in expostulating, by letter, with Joseph Hume, on the injustice of suffering such a man as Dalton to go unrewarded. His claims were acknowledged even by that rigid economist, and soon after the first pension was accorded him.

We have already seen that Dalton declined to avail himself of the offers of his friends to provide him with a competency, which should set him free from the necessity of elementary teaching. This was in the days of his robust manhood; and we think he did right. We know no reason why the man of science, so long as he is full of health, should not take his share in bearing the burden 'under which the whole creation groaneth and travaileth'—why he should be exempt from the common lot of earning his bread by the sweat of his brow. We are sure, moreover, that the joys even of a hard-earned independence will more than compensate, in every case, for the fancied advantages of an undeserved and an inglorious leisure. It is very different when age has overtaken the man who has laboured while he had strength, and who has spent his days in extending that knowledge by which all men are gainers.

Such a one, even though his studies have been of the most purely speculative and apparently unpractical kind, may fitly be saved from the gripe of poverty 'when the grinders cease because they are few, and those that look out of the windows be darkened,' by the kindness of his less gifted but more wealthy fellow-men. But the claims of the worn-out man of science are still greater, when he has been the author of discoveries which have enabled his quite unscientific brethren to 'reap where they had not sown, and gather where they had not strewn.' Then it becomes a matter of justice, not of generosity, that he who has been the invisible sower of the seed which has produced, in some cases thirty, in some sixty, and in some an hundredfold, should receive his tithe of the fruits of the field. The pension which Government allowed to Dalton might be regarded as a generous gift to the author of 'Experiments and an Hypothesis on the Constitution of mixed Gases.' But to him who unfolded the 'Atomic Theory' it was only a moderate, we had almost said a niggard dole. Three hundred pounds a year! What a small fraction was that of the countless sums which he had saved his country—which he had won for her. The application of the laws of combining proportion to the practical arts enabled the manufacturer of glass, of soap, of pigments, of medicinal substances, of dyes, of oil, of vitriol, and of many other bodies of great commercial value, to secure their production without waste, or loss, or any unnecessary expenditure. Dalton could tell such a man, to a grain, the exact quantity of each ingredient which required to be added to produce a given compound. Three hundred pounds a year! If Joseph Hume could obtain as good an account of every £300 sent out of the Treasury, he would be a happy man, and England a happy country.

In the same year, 1833, in which Dalton received his first pension, a number of his friends subscribed the sum of £2000, and employed Chantrey to execute a full-length statue of him in marble. This beautiful work of art, which gives a fine likeness of Dalton, is erected in the entrance hall of the Royal Manchester Institution.

Dalton went to London to give Chantrey the requisite sittings for his bust, and while there was most cordially welcomed by men of science. Nor was this all. Through the influence of Mr. Babbage, the mathematician, of Lord Brougham, who was then Chancellor, and of some other friends, he was presented to William IV. From the account of a Manchester gentleman who was well acquainted with the facts, we learn that 'with great skill all the minute preparations for his appearance in such august presence were made by his friends; and arrayed in the pompous vestments of a Doctor of Oxford, with the scarlet gown and black cap, the silk stockings, the buckles, and the whole paraphernalia of a learned courtier, our townsman mingled in the crowd of soldiers, sailors, statesmen, and divines, who thronged the splendid apartments of St. James's, where he was very graciously received by the King.' Whether his London friends acted wisely in introducing such a man to his Majesty, not as John Dalton, the great chemist, but as Dr. Dalton, of Oxford, we shall not stop to inquire.

In 1834, Dalton attended the meeting of the British Association at Edinburgh, where every sort of kindness and new honours awaited him. The University conferred upon him the degree of LL.D., the Royal Society elected him a member, and the Town-Council presented him with the freedom of the city.

In 1835, he was present at the Dublin meeting of the Association; where all parties, from the Lord-Lieutenant

downwards, vied with each other in extending to him the marks of their esteem.

We have now reached the seventieth year of his laborious career, and it will not surprise the reader that the silver cord should be beginning to be loosed, the golden bowl to be broken at the fountain.

In 1837, when in his seventy-first year, he suffered from a severe attack of paralysis, which left his right side powerless, and also deprived him of speech. He experienced a second slight attack on the 21st of the same month, and for some time both his mental and bodily faculties appeared to be much affected. After an illness of some months, however, his health improved, and his mind began to evince something of its former vigour, though his articulation always remained less distinct than before. We are indebted to the *Manchester Guardian* for these particulars, and from the same able journal we take, with a few slight alterations, the following statements relative to the close of the career of John Dalton :—On the 17th of May 1844, he had a third paralytic stroke, which partially deprived him of the use of his right side, and increased the indistinctness of his utterance. He recovered in some degree from this attack also, and on the 19th of July 1844, was present at a meeting of the council of the Manchester Literary and Philosophical Society, where he received an engrossed copy in vellum of a resolution of that society, passed at its annual meeting, recording 'their admiration of the zeal and perseverance with which he has deduced the mean pressure and temperature of the atmosphere, and the quantity of rain for each month and for the whole year ; with the prevailing direction and force of the wind at different seasons in this neighbourhood, from a series of more than 200,000 observations, from the end of the year 1793 to the beginning

of 1844, being a period of half a century.' Dalton received the resolution sitting, and being unable to articulate a reply, handed a written one, which he had prepared, to his old and attached friend, Peter Clare, Esq., who read as follows :—
'I feel gratified by this testimony of kind regard offered to me by my old associates of the Literary and Philosophical Society of Manchester. At my age, and under my infirmities, I can only thank you for this manifestation of sentiments which I heartily reciprocate.'

This was the 19th of the month ; on the 27th, Dalton was no more !

On Friday, the 26th of July, he retired to his room about a quarter or twenty minutes after nine o'clock ; and going to his desk, on which were usually placed the books in which he recorded his meteorological observations, he entered therein the state of the barometer, thermometer, etc., at nine o'clock ; and added, in the column for remarks, the words 'little rain,' denoting that but little had fallen during the day. His servant observed that his hand trembled more than he had ever before seen it, and that he could scarcely hold the pen. Indeed, the book exhibits, in its tremulous characters and blotted figures, striking proofs of the rapid decay of the physical powers. But there was the same care and corrective watchfulness as ever manifested in this his last stroke of the pen ; for, having written opposite a previous observation, 'little rain this,' he now noticed that the sentence was incomplete, and added the word 'day,' which was the last word that was traced by his tremulous pen. He retired to bed about half-past nine, and spent a restless and uneasy night, but seemed, on the whole, in his usual way when his servant left his bedside at six o'clock next morning.

About half an hour later, his housekeeper found him in

a state of insensibility, and before medical attendance could be procured, though it was immediately sent for, he expired, 'passing away without a struggle or a groan, and imperceptibly, as an infant sinks into sleep.'

The news of Dalton's death, although it must have been looked for by many, was heard with sorrow throughout the whole length and breadth of the land. His townsmen, anxious to express their sense of the irreparable loss they had sustained, resolved to give him a public funeral. But this was not enough; and as an additional mark of respect, his body was 'laid in state' for a day in the Manchester town-hall, and visited by about forty thousand persons. The funeral itself took place on the 12th of August. 'A procession was formed of nearly a hundred carriages, and many hundred persons on foot; the windows were lined with spectators, as well as the roofs of the houses; nearly all the shops and warehouses in the line of the procession, and many in other parts of the town, were closed; four hundred of the police were on duty, each with an emblem of mourning; and the funeral train was about three quarters of a mile in length.' He was buried in the cemetery at Ardwick Green. It has been felt by many that it would have been well if the 'lying in state' at least had been omitted. It lessens the pleasure also with which we otherwise read the accounts of Dalton's burial, to know that the mode adopted in this respect to do honour to his memory was a source of pain and offence to the members of that estimable religious body with which the deceased had always retained connexion. Who were to blame, if the thing is to be accounted as blame-worthy, for this ceremonial, we shall not stop to inquire. It is quite certain that the people of Manchester generally were actuated by no other feeling than that of an earnest desire to honour the

illustrious dead ; and there is something solemn and sublime in the idea of the intelligent thousands of a great city, forgetting for a time the claims of business, attiring themselves in the weeds of woe, and gathering round the bier of a solitary scientific recluse like Dalton. This feeling is heightened by the thought that it was no questionable hero, no noisy demagogue or destroyer of his species, to whom the multitude were doing this homage, but a true high-priest of nature, and a benefactor of his fellow-men.

In stature, Dalton was about the middle size, of strong rather than of elegant proportions. The likeness between his head and face and those of Newton was often observed during his lifetime, and is said to have become more striking after death. When engaged in study, a certain air of severity, such as may be seen on the busts of Newton, shadowed his features ; but the gentle smile on his lips showed even the inexperienced physiognomist that it was deep thought, not angry passion, that wrinkled his brow.

Till his seventieth year he enjoyed robust health, and he was all his lifetime fond of exercise in the open air. He made a yearly journey to his native mountains of Cumberland and Westmoreland, and climbed Helvellyn, and often also Skiddaw. The afternoon of every Thursday he spent at a bowling-green, where he could join with some congenial associates in a turn at the old English game of bowls. We have heard a distinguished professor of chemistry tell that he once called for Dalton at his laboratory on a Thursday, and was directed to look for him at the bowling-green. Dalton quietly apologized for being out of his laboratory, adding that he liked to take a Saturday in the middle of the week. He was entitled to do so, as he did not take one at the end, the seventh day being always a day of hard labour with him.

We have already alluded to a peculiarity in Dalton's vision, which he made the subject of the first paper he read to the Manchester Society in 1794. It consisted in this, that whereas most persons see seven colours in the solar spectrum, he saw only two—yellow and blue; or, at most, three—yellow, blue, and purple. He saw no difference between red and green, so that he thought 'the face of a laurel-leaf a good match to a stick of red sealing-wax; and the back of the leaf answers to the lighter red of wafers.' When Professor Whewell asked him what he would compare his scarlet doctor's gown to, he pointed to the leaves of the trees around them. Dalton found nearly twenty persons possessed of the same peculiarity of vision as himself. The celebrated metaphysician, Dugald Stewart, was one of them, and could not distinguish a crimson fruit like the Siberian crab from the leaves of the tree on which it grew, otherwise than by the difference in its form.

This failure to perceive certain colours is by no means rare, and has excited a great deal of attention. The continental philosophers have named it *Daltonism*, a name which has been strongly objected to by almost every English writer who has discussed the subject, on the ground of the inexpediency and undesirableness of immortalizing the imperfections or personal peculiarities of celebrated men by titles of this kind. If this system of name-giving were once commenced, it is difficult to see where it would end. The possession of a stutter would be called Demosthenism; that of a crooked spine, Esopism; the lack of an arm, Nelsonism; and so on, till posterity would come to connect the names of our celebrated men, not with their superior gifts, or accomplishments, or achievements, but with the personal defects which distinguished them from their more favoured fellows.

Professor Whewell sought to better the matter by naming those circumstanced like Dalton, *Idiopts*, from two Greek words, signifying peculiarity of vision. But to this name it was justly objected by Sir David Brewster, that the important consonant *p* would be very apt to be omitted in hasty pronunciation, and so the last state of the Idiopt be worse than the first. Others have suggested various terms of Greek derivation, such as *parachromatism*, none of which, however, are sufficiently distinctive. The name 'Colour-Blindness,' proposed by Sir D. Brewster, seems in every respect unexceptionable.[1]

We are more concerned to know that Dalton supposed the peculiarity of his vision to depend upon the vitreous humour (the liquid which fills up the greater part of the ball of the eye), being in his case of a blue colour, instead of colourless, like water, as it is in the eyes of those who distinguish every tint. His own words are—'It appears, therefore, almost beyond a doubt, that one of the humours of my eyes, and of the eyes of my fellows, is a coloured medium, probably some modification of blue. I suppose it must be the vitreous humour; otherwise I apprehend it might be discovered by inspection, which has not been done.'[2]

After Dalton's death, in obedience to his own instruc-

[1] The reader who is curious in regard to this matter, will find a very elaborate article on the subject, entitled 'On Daltonism, or Colour-Blindness,' in the *Scientific Memoirs*, an occasional periodical published by Richard Taylor, Red Lion Court, Fleet Street, London.

[Since this was written, a series of elaborate researches have been issued by Dr. Wilson, embodying the results of his observations during several years, on the nature and extent of this peculiarity of vision. The volume is entitled 'Researches on Colour-Blindness,' and may be obtained from Messrs. Edmonston and Douglas, Edinburgh.]—Ed.

[2] Manchester Memoirs for 1798, p. 43.

tions, his eyes were examined by his medical attendant, Mr. Ransome. The vitreous humour was not found, however, to present any blue tinge, but, on the other hand, was of a pale yellow colour: neither did red and green objects looked at, through it, used as a lens, present any difference in tint to an ordinary eye, as they should have done had Dalton's hypothesis proved true. Were his view, indeed, the correct one, blue spectacles should induce the same peculiarity in the eyes of every one, which they are well known not to do. Everything, in truth, points to the cause of the colour-blindness, residing not in the optical apparatus of the eye, but in some peculiar condition of the brain or sensorium. So much for the physique of Dalton.

In endeavouring to form a conception of his mental peculiarities, we shall be assisted by comparing him with some of his great fellow-chemists. The labourers to whom chemistry has been indebted for its greatest advances admit of a natural division into two great classes. The one of these, and by far the smaller, contains men possessed of enthusiastic, imaginative, poetical temperaments, of sanguine, hopeful spirits, and great rapidity, subtlety, and comprehensiveness of mind. Such pre-eminently was Davy; such is the great living chemist Liebig; and if we accept a very subtle fancy instead of a far-stretching imagination, such too was Priestley.

The other and larger class consists of men in whom the poetical element was at a minimum, who were characterized by great patience, self-concentration, and perseverance in thinking; for whom the working motto was, '*Non vi sed sæpe cadendo;*' and in whom great self-possession and self-reliance were strongly developed, producing indifference to the opinion of others, and, in extreme cases, an almost repulsive hardness, sternness, and severity of character.

To this class belong Black, Cavendish, Wollaston, Bergman, Scheele, Lavoisier, DALTON, and, if we include the living, and confine ourselves to our own country, Faraday, Graham, and Thomson.[1] Thinkers of both these classes have done, and will yet do, excellent service to chemistry. We sum up their peculiarities in a word, if we say, with the late Dr. Henry, that the great object of the first class is to discover truth ; of the second, to avoid error.

Dalton possessed, in an eminent degree, the characteristics of the class to which he belonged. He was so indifferent to the opinion of others, that he could never be persuaded to reply to the attempts which at one time were made to exalt Higgins above him ; so self-reliant that, in the face of overwhelming evidence, he refused for a long time to put faith in Gay-Lussac's discoveries concerning combination by volume, because they contradicted a hypothesis of his own. To the end of his days he persisted in calling the atomic weight of oxygen 7, though all other chemists were unanimous in making it 8.

Like Newton, he referred the discoveries he had made, not to the power of genius, but to the industry which he had brought to bear upon their elucidation. At the anniversary meeting of the Pine Street Medical School, Manchester, he thus replied to a toast embodying his name :— 'With regard to myself, I shall only say, seeing so many gentlemen present who are pursuing their studies, that if I have succeeded better than many who surround me, in the different walks of life, it has been chiefly, nay, I may say almost solely, from unwearied assiduity. It is not so much from any superior genius that one man possesses over an-

[1] [Professor Thomas Thomson of Glasgow cannot now be ranked among the great living chemists. He died in 1852.]—ED.

other, but more from attention to study and perseverance in the objects before them, that some men rise to greater eminence than others. This it is, in my opinion, that makes one man succeed better than another. That is all I shall say concerning myself.' In all this there was no affectation. One who knew Dalton well, said of him during his life, 'If led into a discussion on any branch of science or philosophy with which his name is connected, he never hesitates to explain where his own discoveries begin and end, and what portion of the ground has been trodden by others.' Neither did he hesitate to entitle his volumes on heat and atomics, '*New* System of Chemical Philosophy.'

He was very methodical and orderly in his habits. We have seen that the Thursday afternoon was spent in the bowling-green. He was equally regular in attending the meetings of the Society of Friends, at which he was present twice every Sunday. On the same day, he was in the habit, for more than forty years, of dining at a friend's house; and even when the family were absent, he paid his accustomed visit.

His love for truth was very great, of which one striking example may be given. A student, who had missed one lecture of a course, applied to him for a certificate of full attendance. Dalton at first declined to give it; but, after thinking a little, replied—'If thou wilt come to-morrow, I will go over the lecture thou hast missed.'

Such was Dalton; a simple, frugal, strictly honest, and truthful man. For the independence, gravity, and reserve of his character, he was, doubtless, much indebted to his birth as a Cumberland yeoman, and his long connexion with the Society of Friends. The individuality of his nature showed itself in his great mathematical capacity, his tho-

rough self-reliance and power of patient, persevering work, the native clearness of his intellectual perception, and the extraordinary power of fearless generalization which he brought to bear upon what nature unfolded to him. In the latter quality, in particular, he excelled every one of his scientific contemporaries.

The inhabitants of Manchester have announced their intention of erecting a monument to Dalton's memory. We trust that the proposition of founding a chair of chemistry, especially for the exposition of chemical atomics, will take the precedence of every other, as the best means of carrying out that intention. Every one, we think, must feel that bronze statues, or other costly erections, would be altogether out of keeping with the character of the plain Quaker man of science. A 'Dalton' chair of chemistry, on the other hand, would be a fitting memorial, and in conformity with the wishes of him whom it is intended to honour. Dalton, it is well known, left the sum of £2000 to endow such a chair at Oxford, but revoked it before his death, with the view, it is believed, of giving the money to friends who had assisted him in his early days.

We would hint, moreover, that even the enduring brass and the everlasting granite crumble down under the tooth of Time, and are at best but dumb remembrancers of him whom they seek to save from oblivion. The living voice of the professor from his chair would keep in perpetual remembrance the name of Dalton, as the paid and appointed chantings and masses of the Roman Catholic priest recall, if but for a moment, the memory of the long-forgotten dead.

We offer these suggestions with all deference to those who seek, by some befitting token, to keep before us the memory of Dalton, because we should grieve to think that

a great sum of money had been spent for this purpose in vain.[1] So far as he himself is concerned, we have no fear. Dalton will never be forgotten. He is the second Newton of English physics, and will go down to posterity along with the first. Men will think of them together, and compare them to the double stars which a later astronomy has unfolded to our view—each a sun, shedding light on the other; both stars of the first magnitude, revolving round, and pointing towards a great centre, which they equally make manifest and obey; even Him who is the first and the last, the Alpha and the Omega, the beginning and the end of all things.

[1] [The results of the deliberations regarding a monument to the memory of Dalton, have been the erection of a bronze statue, opposite the Infirmary in Manchester, and the naming after him of one of the thoroughfares in that city.]—Ed.

THOUGHTS ON THE RESURRECTION.

AN ADDRESS TO MEDICAL STUDENTS.

'The children of this world marry, and are given in marriage: but they which shall be accounted worthy to obtain that world, and the resurrection from the dead, neither marry, nor are given in marriage: neither can they die any more: for they are equal unto the angels; and are the children of God, being the children of the resurrection. Now, that the dead are raised, even Moses showed at the bush, when he calleth the Lord the God of Abraham, and the God of Isaac, and the God of Jacob. For he is not a God of the dead, but of the living: for all live unto him.' Luke xx. 34-38.

It is a remarkable peculiarity of the Bible, that although one of its chief objects is to reveal to man a future life and a world to come, it avoids, with unfailing reserve, any minute or pictorial description of the immortal body or the heavenly state.

It offers proofs of their reality, such as fully satisfy the unprejudiced intellect, and fill with delight the sanctified heart; but, unlike the sacred books of all false religions, it furnishes very little for the imagination to lay hold upon; and even St. John, whose Apocalyptic visions are so far an

exception to the rule of reserve, tells us, in one of his epistles, that 'it doth not yet appear what we shall be.' Nor should it be forgotten that the Apocalypse was not revealed till long after the Saviour's ascension, and was left to mankind with all its sublime mysteries uninterpreted, a shadow even yet of good things to come.

And in no part of the Word of God is the silence in reference to the other world more remarkable than in the teachings of the Saviour. He could have told his disciples much regarding the future state, which they longed to know, and about which they doubtless often questioned him, but his answers—as to him who asked, 'Lord, are there few that be saved?'—are such as to silence without gratifying mere curiosity, and to remind the inquisitive questioner that the great problem for him is his personal relation to that invisible world, the secrets of which are only made known to those who have passed within its portal.

Our Saviour, however, as we see in the case of the sisters of Bethany, before the resurrection of Lazarus, did not refuse to enlighten his followers on the purely spiritual relations of the heavenly world; and the passage which I have read in Luke xx. 34, forms one of the most striking examples of his mode of referring to these. It is, on the whole, the most full and explicit exposition of the future state of happy human spirits which the Lord Jesus Christ gave upon earth, and none more full or explicit was afterwards dictated by the Holy Spirit to any of the inspired writers. Altogether, accordingly, the passage is a very remarkable one, and worth our consideration for a short season.

The occasion which led to our Lord's brief discourse was a peculiar one. He was at the period, as we learn from

the context, in great favour with the people. He had entered Jerusalem amidst their hosannas. He taught daily in the temple, and 'they were very attentive to hear him.' For the time, he was so great an object of interest to the multitude, that the chief priests and the scribes and the chiefs of the people, though thirsting for his blood, dared not lay hands upon him. They sought, therefore, to entrap him into statements which would render him obnoxious to the Roman Governor; and just before the incident under notice occurred, they had been signally discomfited in their endeavour to extract from him an unpopular, and, from a Roman point of view, a disloyal answer to the ensnaring question, 'Is it lawful for us to give tribute unto Cæsar, or no?'

The Sadducees now appeared more prominently on the scene, perhaps with less malignant intentions towards the Saviour than their more influential and popular rivals the Pharisees, but certainly not less anxious than they were to bring Christ and his doctrine into contempt. They prepared, accordingly, with great artfulness, a query which they addressed publicly to the Lord. Their object plainly was to invest with ridicule the doctrine of the resurrection, which they denied, but at the same time to give the Saviour no direct opportunity of vindicating that doctrine, or the Pharisees an occasion of triumphing over them in the presence of the people, as convicted of error. On the other hand, they affected to believe in the resurrection, and, as if sincerely desirous to have a difficulty connected with their belief in it removed, they brought that difficulty in the form of a question before the Saviour. It was founded on a well-known and remarkable statute of the great Hebrew lawgiver, and if, as probably seemed to them not unlikely, Jesus should in his reply disparage an enactment given to

the nation by Moses, they might trust to both the Pharisees and the multitude making common cause with them against him.

Whether the case to which they referred—of one woman being successively the childless wife of seven brothers, all of whom she survived, dying a childless widow—was the record of an actual fact, or only what lawyers at the present day would call an A B or hypothetical case, is not of much moment. It is quite possible the reference was to a known family history, and the temptation we may feel to pronounce on the improbability of its occurrence will be lessened, if we remember that in the early ages of the Hebrew people, polygamy was sanctioned, and that, as the story of Ruth shows, we must include under the term brethren, not merely brothers and half-brothers, but much more distant kinsmen. This, however, is immaterial. The question, which of this woman's earthly husbands should have her to wife in the resurrection, about which the Sadducees affected so much concern, might, in its essentials at least, have been raised in connexion with the everyday case of a widow contracting marriage. To all the bystanders, in addition to the examples which their own circles of relationship presented, the case of Ruth must have been familiar ; and it may not be inopportune to remark, that by her second marriage, Ruth, whose great-grandson was king David, became an ancestress, according to the flesh, of the Saviour himself.

At all events our Lord found no fault with the question, but proceeded at once to answer it ; and we may imagine how eagerly the crowd watched for the answer. It was such a question as the idle curiosity of man loves to raise. It had a human interest about it, as affecting the relation in which the different members of a family would stand to

each other in another world, if there should prove to be such a thing. At the same time, it apparently involved no moral considerations, so that the most sinful and conscience-stricken among the bystanders might await the reply without fear or trembling. The reply was given, silencing and startling all. The mocking question was disposed of in a word : 'In the resurrection' (to use the language of Matthew in describing the scene), 'they neither marry, nor are given in marriage.' But the cunning Sadducees were not allowed to escape. Instead of being credited with their pretended faith in the resurrection, they were pronounced ignorant of the Scriptures and of the power of God. They were told in the hearing of all the people, not only that the resurrection was a certainty, but that the subjects of it would be immortal, the equals of the angels, and that Moses, for whom they affected so much reverence, was a witness to all this, inasmuch as he had recorded the words of Jehovah himself, 'I am the God of Abraham, of Isaac, and of Jacob,' a God not of the dead, but of the living. In short, all the doctrines of Scripture in which the Sadducees were notorious disbelievers—namely, the rising of the dead, the endless life beyond the grave, the testimony of Moses to both, and the existence of angels—were, at their own unwilling instances, pronounced upon and affirmed to be true, in reply to the cunningly devised question, which in their estimation was so framed as to render impossible touching on such points at all. They were utterly silenced, but all who listened were amazed at the reply, and from that day forward, as the evangelists tell us, no one durst ask the Saviour any question.

It is not, however, with the discomfiture of the Sadducees that we are concerned. We may rather, indeed, be grateful to them for having secured to us and to all their mortal

successors, so full and explicit a declaration of the reality and results of the resurrection.

To some remarks on that great Christian doctrine, as dwelt upon by our Saviour in the memorable words of which we have spoken, and as illustrated by his inspired servants who wrote the Scriptures of the Old and New Testaments, I now ask your attention.

I have chosen this subject because, whilst none are more capable than you of appreciating its difficulties, as involving a physical truth concerning the body, many Christian persons seem to me to attach much less importance to the future resurrection of their own bodies, than the Bible intended they should do. I do not mean by this to say, that they deny or disbelieve the resurrection. On the other hand, there is probably no Scripture doctrine less disputed about than that of the resurrection. Men receive it as a whole, or reject it as a whole. To disbelievers in Christ it has no meaning, or only an unwelcome one. By his followers it is too often regarded, at least in its relation to themselves, simply as a mystery which is not to be denied, but is as little to be understood on this side the grave. In particular, I find some truly pious persons understanding by the resurrection of the body, only an assurance of immortality of the soul; whereas the Bible certainly teaches *both* doctrines, and, teaching both, must have a special lesson to convey by each. Again, I find devout Christians, especially those who have known much sickness, and have vivid imaginations, looking at the resurrection of their own bodies rather as a trial of faith than an encouragement to perseverance. These bodies have been to them sources of so much suffering, that they would rejoice to be done with them for ever, and to go, if it should so please God, unclothed into the presence of the Father of Spirits. With

such a hope, however, no inspired writer has any sympathy. On the other hand, exactly in proportion as they insist on the vileness of the sinful body of fallen man, do they enlarge on the certainty of its future existence, and its fitness to be clothed with glory, honour, and immortality.

And in so arguing, they but follow the example of their Lord and Master, who ever speaks of the resurrection as the gateway through which, following in his steps, they should ascend to the blessed rest, and become capable of the fruition which he had purchased for them beyond the grave. Witness his statement on the occasion under notice. He announces as a prerogative of the happy dead, the essential or intrinsic and angel-like deathlessness of their future bodies.

There is something very expressive to my thinking in the words,—'Neither *can* they die any more." I put the emphasis on the word *can*. The children of the resurrection are not merely to be walled off, as it were, from all deadly foes and mortal influences, but they are to be rendered incapable of death. It shall have no more dominion over them. They shall not only never die, but they shall be undying.

Few, I think, can have sat beside the deathbeds of others, especially of dear relatives, and witnessed the lingering illness and long-protracted agonies which so often precede the last struggle, without looking forward with horror to the possibility of all that agony being endured again. It may be that we misinterpret some of the physical precursors or accompaniments of dissolution, and regard as signs of suffering what are but unfelt movements of the organic machine. It is just as likely, however, on the other hand, that we misconceive some of the tokens of bodily and mental agony, and that what we, for example,

regard as painless and serene repose, may be the pent-up, iron-bound anguish and horror of an awful nightmare, the paralysing shadow of a spectral presence. At all events, the death of a sinful mortal is in every case a dread reality, and to be assured that 'they who shall be accounted worthy to obtain *that* world,' shall never know again the dreadfulness of dying, is a great consolation to all who have seen others die in the Faith, and have hope of a blessed resurrection themselves. And, as if this were not enough, the Saviour adds, in startling illustration of the reality of the assurance that they do not die any more: 'for they are equal unto the angels,' literally *angel-equals* (ἰσάγγελοι). The reference here, I apprehend, is not to equality in all respects, which may or may not exist, but to equality in respect of essential immortality; and the significance of the allusion seems to lie in the fact that an angel is a spirit, I do not say without a body, but without a mortal body; and thus to be equal to an angel is to be angelically immortal.

Second in prominence to the statement just noticed, is the revelation of our Saviour, that the resurrection-body is to be in a true sense identical with our present body. The statement with which our Saviour's reply opens, appears to leave this point undetermined, and rather to discountenance than favour the idea that our future bodies shall exhibit relationship to our present ones. There is to be no marrying or giving in marriage in the world to come. The closest earthly ties which bind families together shall cease there. We shall seemingly stand alone, and the life that we shall live, shall be, as the closing words of the Lord imply, 'a life unto God.' At the same time, however, we are told that God is the 'God of Abraham, the God of Isaac, and the God of Jacob;' a remarkable statement, and one which especially startled those who heard it. Many prob-

ably perceived for the first time that Moses taught that the Lord of Heaven is not merely the omnipotent ruler of a vast assemblage of nameless spirits of just men made perfect, but that he is the God and Father of the children of the resurrection, each one of whom,—Abraham, Isaac, and Jacob,—lives to God, as if he were his only redeemed child.

Nor is it a special privilege of the ancient patriarchs thus to have their individuality recognised by God. A pious Jew reading the account which Moses gives of the bush which burned with fire and was not consumed, might infer, from the words of Jehovah, that the great fathers of his race were acknowledged in their glorified personality by God in heaven, and yet hesitate to infer that he might hope for a similar recognition of his own personality, even though he should be carried by the angels into Abraham's bosom. But the Saviour includes all those blessed children of the resurrection in the same category: 'For all,' he says, 'live unto him.' Less, accordingly, cannot be deduced from the whole statement, than that among 'the dead that are [or shall be] raised,' are Abraham, Isaac, and Jacob, who after their resurrection shall be recognisably the Abraham, Isaac, and Jacob they were upon earth; and in like manner, all who rise to glory with them shall preserve, however changed, the identifiable personality they possessed before death. With this element of unchanged personal identity is associated that of recognition by fellow-immortals, as well as by God. On the question of mutual recognition, however, the Saviour says nothing; nor could a reference to it be expected in a statement the main object of which was to teach all who heard it that heaven is not a place where even the purest earthly passions shall be fed, but a holy habitation, where he before whom the unfallen angels veil their faces, is the great and sufficing object of regard. At the

same time, the doctrine of mutual recognition is, I think, implied in what the Saviour said, Abraham shall know Isaac, and Isaac shall know Jacob ; and the partakers with them of a blessed resurrection shall share their privileges. Or rather, perhaps, I should express it thus :—The patriarchs and their fellow-heirs of glory shall be susceptible of mutual recognition, and if recognition does not openly take place, it shall be for other and higher reasons than that the conditions of its occurrence are not provided. But this is, after all, a secondary matter, on which it is not at all my purpose to dwell. Whatever be the rule of heaven on this question, we may be quite sure it will be found fully to content us.

Let us turn from all minor considerations to the great doctrine of the resurrection with which the Saviour silenced the Sadducees, and startled even the most orthodox of the Pharisees, by proclaiming it not only as his own doctrine, but as one which the great lawgiver of the Hebrews had learned from the utterance of God himself, and, ages before, had taught to all the people.

The great *probability* of our souls or spirits surviving death and proving immortal has been realized by the wiser men of many an ethnic race, although Christ, and Christ alone, brought life and immortality to light. But that our bodies should live again, and be made as immortal as our souls, is a result towards which natural theology has never pointed as a conclusion which it could independently reach, or was greatly inclined to favour. The wise Greeks mocked when Paul spake of the resurrection of the dead ; and the wild Africans laugh our missionaries to scorn when they tell them that the dead shall rise again. Yet it is a doctrine which the Saviour put ever in the foremost place—teaching it in words ; proving its possibility by raising the dead ;

and demonstrating its certainty by himself rising from the grave.

It is impossible, then, to have any sympathy with those who speak as if the resurrection were a secondary or supplementary Christian doctrine. It is a central and cardinal one, and for the following among other reasons :

Firstly, It makes our whole existence from its germinal beginning, onwards to its fullest development in the most remote eternity, the evolution of one nature. We are, then, soul and body upon earth. We shall be men, soul and body, in the world to come. We shall not be human existences here, and spiritual existences there ; but human existences in both. We shall be inconceivably changed, 'and it doth not yet appear what we shall be,' but we shall be children of Adam for ever, and our life shall know no break from its first dim dawn to its midday brightness in the world of bliss, or its midnight setting in the world of woe. When we stand before God, in presence of the Great White Throne, and are judged every man according to his works, it shall not be possible for any one to say that the body in which he stands is a strange, untried one, in which on earth he never sinned or repented, and on which it is unjust that punishment should now fall, and unbefitting that glory should come. All transformed though it shall be, the possessor of each body will feel that it is his own once 'sweet flesh.' It will gather round our spirits as a natural garment. The judgment which is given on the deeds done in the body, however woful, will be felt to descend on the very body in which the deeds were done. The tears which God shall, once for all, wipe away from the faces of the blessed, shall assuage the weeping of the very eyes, wonderfully changed, but felt to be the same, that wept day and night upon earth ; and the consciousness that

it shall never know pain again, shall thrill through the very frame that once agonized in the mortal life, like the ripple on a lake, which, though now serene as the clear sky above it, has in it tokens that it fell from heaven, and has carried with it signs of the battles with the rocks over which it was flung, and the whirlpools in which it wrestled before it reached the land-locked valley below.

There are, perhaps, no created beings but ourselves to whom this continuity of bodily existence is given. It is at least no prerogative of the lower animals, and it appears to be one of those things which the angels desire to look into. At all events, it confers upon our bodies an awful indestructibility, at thought of which the enduringness of suns or stars becomes as nothing, and we realize in a new and almost terrible sense, that we are fearfully and wonderfully made.

Secondly, The resurrection identifies us with Christ in a very wondrous way ; one, indeed, compared with which all other aspects of the resurrection are of secondary importance. In the Epistle to the Hebrews, we have condensed, as it were, into one shining, burning focus, the light of revelation on this great matter. Jesus Christ the Son of God, the brightness of his glory, and the express image of his person, is declared to have been made a little lower than the angels, for the suffering of death, that he by the grace of God should taste death for every man. As the eldest of his brethren, the nearest to the Father of the children of God, it is affirmed of him that 'forasmuch as the children are partakers of flesh and blood, he also himself took part of the same ; that through death he might destroy him that had the power of death, that is, the devil ; and deliver them who through fear of death were all their lifetime subject to bondage ;' and it is added em-

phatically, 'He took not on him the nature of angels, but he took on him the seed of Abraham.'

Now, what do those statements mean? They plainly teach us, not as the initiation, but as the echo of the universal evangel, that the Son of God stooped to wear a mortal body, and become the Son of man. They tell us further, that he did so that he might live a human life of holy obedience to his heavenly Father, which should be the one unexampled pattern to the race, of perfect, spotless manliness from the cradle to the grave; that he might die a sacrificial death, and become a propitiation for the sins of the world;—and they also reveal, that in so dying he laid down a life which none could take from him; that he left in the grave a body which corruption could not touch; and that he rose from the dead with the pierced side and crucified hands in which he was slain, as one over whom death had no dominion, who himself held the keys of death and of the invisible world. Further, the Scriptures declare that in the very heaven of heavens, whither he has passed to the right hand of the Majesty on high, he wears, however transcendently glorified, a body which marks him, all divine though he is, as still the Son of man.

The significance of our resurrection lies in those great revelations. Though the reason for it may be beyond our discovery or apprehension, if we believe the Bible, which alone teaches the doctrine of a resurrection, we cannot but acknowledge the truths on this point which they unfold. The only man (for the sinless Adam is no exception) who faultlessly traversed the entire circle of human obligations, alike to God and man, has never, since the 'Word was made flesh,' except between the crucifixion and the resurrection, ceased to wear a human body. He wears still in all his exaltation what his chosen apostles love to dwell upon as

his 'glorious body;' and these facts should be enough to show that we neither follow the example of our Lord and Master, nor his disciples, if we think lightly of the resurrection.

And to say this is to say infinitely too little. It was to bless us; to save us; to redeem us, that the only begotten Son of God laid aside his glory, and, born of a woman, endured the cross, despising its shame; and our bodies must be as indispensable to our future as to our present life, else he whom angels worship, and all the hosts of heaven adore, would not, as the First Born among many brethren, give us assurance of his sympathizing humanity by retaining the title Son of man, or suffer his servants to exult in the prospect of the Lord Jesus Christ himself changing their bodies, that they may be fashioned like unto his body.

Our bodies thus, according to Scripture, are immortal realities. Except through the interval between death and resurrection, which, however long, will in a timeless state seem perhaps but a moment, they shall not wait for our souls to acknowledge them, but as independent, co-ordinate existences, will claim half of our individuality as theirs by God's law. In the light of this truth, what deep meaning attaches to the solemn warnings of the apostles, to keep our bodies under subjection; to flee youthful lusts; to be temperate in all things. Who that realizes the deathlessness of his body, will weaken it by intemperance, enervate it by luxury, stain it by licentiousness, or befoul it by crime! I know not which is more the child of the devil, he who ascetically despises that body in which, before they fell, Adam and Eve stood before God and His angels, naked but not ashamed; or he who is sorrowful solely because he fears that his soul is in reality immortal, and who would be

thankful to have only a body in which to-day he might eat and drink, and to-morrow might die.

Let us not forget that as in Adam all died, so in Christ all are made alive again. Through the sinful body of the first Adam, death has come upon us all; through the sinless body of the second, life and immortality have been brought to light. The incarnation of the Son of God was the stooping of the Lord of all beneath the lowly lintel of a human tabernacle. It is now a temple of the Holy Ghost, for all who will listen to him who stands at the door and knocks. Alas! it is also a habitation of unclean spirits to those who refuse when the Master calleth!

It is in both cases an imperishable edifice, and the style of its architecture remains for ever unaltered after death sets his seal upon its closed doors.

Thirdly, We are made one with God through Christ, whether for weal or woe, by the Saviour having worn on earth a human body, and by his wearing now in heaven that body with which he ascended into glory. The Lord of all has not been ashamed to call us brethren, nor has he shrunk from being born of a woman, and being tried and tempted as we are, though without sin; and therefore no child of man, whether in this world, or in the world of bliss, or in the world of woe, can refuse allegiance to him as the highest of men, as well as God unapproachable.

If such be the case, we cannot give too great heed to the doctrine of the resurrection; and it is one, I venture to say, which offers fewer obstacles to a candid mind than most contained in revelation; inasmuch as, being an inscrutable mystery, we must deal with it as a whole. If satisfied, accordingly, that the Holy Ghost affirmed its reality, we can accept it as a matter of faith, on which, when we be-

come subjects of the great change which it predicts all men will undergo, we shall learn as much at least of its meaning as it is befitting we should know.

It might seem at first sight that, treating of a great physical change which awaits our bodies, the doctrine of the resurrection should be amenable to the criticism of physical science; and so assuredly it is, but after all the most sceptical philosopher could but say, when asked if our bodies should rise again, that he could reply neither yes or no. There is not certainly a single fact in physical science which contradicts the possibility of the resurrection; whilst there are multitudes of facts, such as the phenomena of germination,—so grandly referred to by St. Paul in his magnificent exposition of the rising of the dead,—and the change of the caterpillar into the butterfly, which assist us in believing in the certainty, and even so far in realizing the nature of the great change.

Yet, doubtless, there are difficulties, as the church of Corinth felt, in vividly appreciating the possibility of the resurrection, and all of you must have experienced them.

The only effectual cure for doubts of this kind is re-examination, with prayer for Divine guidance, of the proofs that there will be a resurrection. Let us but thoroughly believe that it is a revealed and central doctrine of Scripture, as it so certainly is, and we shall find its mysteriousness no longer dismay us. It was a mystery to the chosen apostles, who had heard Christ proclaim its reality in the presence of all; who had seen him raise from the dead those who had been laid in the grave; who, on the Mount of Transfiguration, beheld beside him Moses and Elias, visitants from the invisible world; who had witnessed him die, and revive, and ascend to heaven; who had themselves, in his name, raised the dead. What to them, there-

fore, was a mystery, according to the explicit declarations of Paul and John, may well be one to us.

At the same time, let me offer you a suggestion on one point. In endeavouring to realize the resurrection to ourselves, not as a mystery which faith alone can receive, but as a physical truth which the intellect can to some extent grasp, we encounter *two* difficulties: the one of these is very obvious, namely, the total resolution of our bodies after death into their ultimate elements; the second is less obvious, but in reality more perplexing, namely, that it is manifestly a law of nature, *i. e.*, of God, that the same matter shall be used over and over again in the sustenance of successive generations of living beings, so that, as should seem, instead of virgin-matter being continually brought from the deeper strata of the globe, to be used once and never again in clothing an organism, a certain comparatively small amount of superficient matter circulates again and again through individual after individual. But if the same matter has formed the bodies of two individuals in different generations, how shall each be provided with a separate body at the resurrection?

Now, on this point, I would remark, that from St. Paul's statement in the fifteenth chapter of 1st Corinthians, we may infer that the resurrection-body will bear such a relation to the present body, as a tree does to its seed. The spiritual body will be identical with the earthly body in the same way that an oak is identical with an acorn, of which it is the evolution, and to which it is indebted for its being an oak, and not a vine or an elm. In some such way, for I do not at all wish to press the analogy too far, our future bodies shall be the same as our present bodies, and yet different; and it is only in such a sense we can look for identity.

Further, the individuality of a seed, or of a human germ, required for its manifestation only a minute quantity of matter. Let me state the physical fact in reference to a vegetable embryo; the statement, *mutatis mutandis*, will apply equally to the embryo of man. The microscopic researches, then, of modern physiology have shown us that an exceedingly small amount of ponderable matter condenses, and, as it were, concentrates in itself the individuality of every germ, vegetable or animal. In other words, the determining power, which, if that germ develop into mature existence, makes it infallibly develop into an oak, into a vine, into an elm; or into a butterfly, into a humming-bird, into an eagle, as the case may be;—this determining power, which constitutes the individuality and continuous identity of the mature organism, is originally located in a microscopic atom of matter. The moment that germ begins to develop, it exchanges those primary particles for others, not merely, remember, adding others to itself, but giving away, as it were, its original self piecemeal, whilst, by a process utterly mysterious, the individualizing power is transferred to the new particles, so that months after the grain of wheat is dead and gone, a blade and stem, taking their characters from it, grow green and ripen, and finally produce grains identical with the perished one.

I would, accordingly, remind you, that in speculating on the physical nature of the resurrection, it is not necessary to think of our personal identity as essentially linked with more than an almost infinitesimal quantity of matter.

It needed all the bulk and weight of matter which have been added between spring and autumn, to secure one single fruitful grain upon the nodding spike of wheat. But the life at the beginning and end of the cycle have been

embodied in the narrow compass of a grain, and the inner essential life of that reposes in a central citadel so small that it can barely be seen, and cannot at all be touched, analysed, or weighed. Give to each of us such a cell as the bodily citadel of Mansoul, and we need no more.

Let me remind you that it is not magnitude, but continuity of body, which the resurrection demands. Death must precede it, but not necessarily destruction of the animal frame. Our Saviour died, but his incorruptible body awaited and received its resurrection. In speaking, however, of the resurrection of the Lord, I cannot but object to the statements of those who allude to the body in which he appeared between the resurrection and ascension, as if that were the body in which he now sits on the right hand of the Majesty on high, or as if it were the type of our resurrection bodies. This is no doctrine of the Bible. It must never be forgotten that Christ was our atoning Mediator, as well as our perfect exemplar. His resurrection had relation to both his offices; and as related to the first, it was the reviving of the very body in which he had been crucified, so that the doubting Thomas was free, if his faith had demanded so much, to thrust his fingers into the holes which the nails had made, and his hand into the pierced side.

But as related to his office as our exemplar, the Saviour's pre-ascension body after his resurrection, differed as much, *mutatis mutandis*, from his present heavenly body, as that of Lazarus, seen on earth, did from what it will be when the last trumpet sounds.

If you have any doubt on this point, recall the fact that even the beloved apostle John declares that 'it doth not yet appear what we shall be,' although both on earth and in vision from heaven he saw more of the personality, if I

may so speak, of the Saviour than any other of his disciples; and that from first to last even those chosen followers who saw the Transfiguration of Christ, and might therefore be supposed to have had some glimpse of the glorified humanity which now encircles him, only vary without altering the key-note of their consenting declaration, that 'flesh and blood cannot inherit the kingdom of heaven;' that mortal eye hath not seen, nor ear heard, what God hath prepared for those who love him; that it is enough for us to know that we may inherit glory, honour, and immortality; and that HE saw Christ afar off, who declared, 'When I awake, I shall be satisfied with thy likeness.' 'Touch me not,' said the risen Saviour in the garden to the adoring Mary, for 'I am not yet ascended to my Father;' and in such words he yet speaks to us. A change as wondrous, and yet as compatible with unaltered physical identity, as that which he underwent on the Mount of Transfiguration, doubtless attended his ascent to heaven, an act in itself altogether beyond the powers of a human body. You do not, however, imagine that I wish to refer to the heavenly body of Christ as inconceivably like his earthly body. Far from that; the Scriptures tell us that 'every eye shall see him, and they also which pierced him,' so that not only the beloved apostle John, and Stephen the martyr, who saw 'the Son of man standing on the right hand of God,' and Paul, who, 'last of all, as one born out of due time,' fell to the earth before the Jesus whom he had persecuted, shall worship their familiar Lord and Master; but they alike who, with nail and spear, pierced his hands and side, and all who consented to his crucifixion, and all who since, in this generation, as in others, have crucified the Lord afresh, and put him to an open shame, shall in a moment know him, and, ah me! 'wail before him.' Nor shall

it less be seen on that day, that as the Lord knoweth them that are his, they shall know him. One look from his benignant eyes shall be enough, and his blessed ones shall recognise that he looks like a Lamb that was slain, and that it is he who hath washed them from their sins in his own blood.

But after fully allowing for all this, we must not overlook the unbroken continuity of existence of our Lord's body. And that this is not a prerogative of Him who in all things has the pre-eminence is apparent from the announcement of St. Paul to the Thessalonians, in which, after declaring that the dead in Christ shall rise first, he announces that those being in Christ at his second coming 'shall be caught up together with them in the clouds to meet the Lord in the air.' This passage, taken along with the declaration of the same apostle in 1 Cor. xv., implies that when the last trumpet sounds, 'all shall be changed,' and that this change is the essential of the resurrection.

Enough, then, of matter to embody our individuality and secure for us a continuous corporeal existence, is all that the resurrection requires. Let us but imagine that it has pleased God to set apart for each child of man so much of the dust of the earth, *i.e.*, of the chemical elements, as shall form this minimum but sufficient medium for the incarnation of his individuality; whilst the Creator also prevents those particles forming the individuality of any other human being, although they may transiently enter into the structure of any number of organisms, to whom for a season they are given in loan.

And when the last trumpet shall awake us, I imagine that those few germ-particles which were sufficient for our embryonic individuality will, unclaimed by any other human being, return to us, and as the true seed of the natural body, be raised and changed into the spiritual body.

I have offered you this suggestion, but I will not enlarge on it; rather will I entreat you to remember that no theory can rob the resurrection of its mystery, nor anything but experience of its awfulness, teach us the nature of the inconceivable change which it will make us undergo.

But before we part, let us not forget, not only that the resurrection awaits us all, but that it has alternative issues. Even in the passage which we have read, it is not obscurely implied that some only shall be accounted worthy to obtain that world where the children of the resurrection are the children of God. And in another of his public statements, the Saviour declares that when the dead hear his voice, 'they shall come forth; they that have done good, unto the resurrection of life; and they that have done evil, unto the resurrection of damnation.'

They shall all be there. All those of whom we have read to-day, the Sadducees and the Pharisees, the scribes, the lawyers, and the people; and we shall be there, and Christ shall be there. Ah! let us lay this to heart, and now, in the days of our mortal life, keep our bodies in subjection, remembering what a solemn future awaits them, realizing that God desires us to make them temples wherein the Holy Ghost may dwell, and that Christ has shed his precious blood to cleanse us from all sin and uncleanness.

And we will close with the prayer for one and all of us, that as we have borne the image of the earthly, we may bear the image of the heavenly, and all live unto God; so that when this corruptible shall have put on incorruption, and this mortal shall have put on immortality, we shall be able to say, 'Death is swallowed up in victory.' Thanks be unto God, who giveth us the victory, through our Lord Jesus Christ! Amen.